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EDITED BY J McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

JANUARY, 1925

ANIMAL FLIGHT

By AUSTIN H. CLARK

SMITHSONIAN INSTITUTION

One of the most interesting phenomena connected with many of the animals that live on land, as well as some that live in water, is the ability they possess of traveling through the air. The possibility of passage through the air assists the animals in their struggle for existence in four main ways.

Among most insects flight serves merely to distribute the various types more widely and more evenly than would otherwise be possible for these small creatures, thus enabling them more efficiently to make use of the food supply. For instance, you plant some cabbages in your garden. Soon some bright green caterpillars appear upon them. How did they get there? Their mother, a small white butterfly, in flying about discovered them. She was raised on someone else's cabbages, possibly miles away.

The uncountable myriads of insects cruising through the air all summer day and night searching for a place to lay their eggs or for a mate form an important food supply themselves, as their total bulk is very large, and many birds, like swallows, most bats, and many other insects live exclusively upon them.

Hope of escape from enemies alone impels the flying-fish and flying-squid to journey through the air, and many birds use their wings only under similar conditions.

Without the power of flight bees could not store their honey, nor could most birds find sufficient food. The food of vultures and the larger birds at sea, for instance, is widely scattered, and to live at all such birds must be enabled to inspect an enormous area each day.

Before taking up flight in detail let us digress a bit and see how the mind of man has been influenced by the sight of birds and bats and insects passing easily through the air from place to place.

From the very earliest times of which we have a record and among all the human races one of the most strongly marked of

human yearnings has always been the desire to fly, to be able like a bird to leave the earth and to soar higher and higher until all earthly things are left behind. This desire to fly is reflected in the folk-lore and stories of all peoples, and to a greater or lesser extent in all religions.

The most conspicuous soaring bird, the eagle, some variety of which occurs almost everywhere, has been adopted as a national, tribal or family emblem to a greater extent than any other animal or object. You all have heard of the American eagle. He figures on the President's flag, on many of our coins, sometimes on our postage stamps, on much of our official letter paper, and on the caps of our army and navy officers. We use the eagle to designate colonels in the army and marine corps, and captains in the navy; and in the army further for all "unattached" officers, and officers of the General Staff. Formerly our generals also wore the eagle, combined with two stars. We used to call one of our coins the "eagle," and more than one hundred of our towns and villages have "eagle" in their names.

While the eagle and the falcon are everywhere associated in the public mind with noble and sublime ideas or aspirations, the creatures that fly by night suggest to all peoples something mysterious and unnatural, and give rise to feelings of awe and dread. The owl is regarded with superstitious fear in many countries, and always is a symbol of something either harmful or at least uncanny. He is feared or distrusted, but never respected. We speak of people sometimes as "wise old owls," though we never apply this term to those we really hold in high regard. The bat is the most characteristic and conspicuous of night-ranging creatures, and in the daytime completely disappears. It is thus quite natural that in the minds of superstitious peoples the bat should be the preeminent symbol of darkness and of mysterious evil. Malignant spirits and the devil are usually shown with bats' wings in contrast to good and kindly spirits and angels, which are depicted with birds' wings.

Optimism, or a tendency to look upon the cheerful side of things, is one of the most fundamental traits of human nature. Wherever we have in our language two contrasting words differing from each other in the occurrence or absence of the prefix "un-" meaning "not," this prefix is always placed before a word of good import and never before a word of evil import, showing that our habit is always primarily to contemplate the good and only secondarily to consider the bad in the world about us. This tendency has brought about a curious transformation in the character of one of the oldest and most universally present of all symbolic animals, the dragon.

In all the ancient Asiatic and European civilizations the flying dragon has played an important part. From very early days, perhaps so long ago as 5000 B. C., to the present in China and Japan, and also in England, as shown on the reverse of the British sovereign, the reptilian dragon with its bat-like wings has preserved an astonishing constancy of form. But, as has been pointed out, a curious transformation took place in Asia Minor and the Mediterranean countries, from Babylonia and Egypt through Assyria to Greece. The wings, which at first had been associated with the fore limbs of the typical dragon and had been bat-like, became bird-like, and then were placed on the shoulders of the lion and of the horse, and finally on man himself, as we see on the great columns of the Greek temples of Ephesus. But all these flying animals are historically descended from the same common stock as the dragons of China and Japan and St. George's dragon of England which still preserve the aspect of reptiles. The Bishop of Exeter regards the Hebrew cherubim as probably originally dragons, and the figure of the conventional angel is merely the human form of the dragon.

Besides the eagles, bats and dragons there are many other flying creatures of less, though still far-reaching, significance as symbols. Such are the dove of peace, the rooster, Egypt's sacred ibis, storks and swans, the "quezal" of Guatemala, and a host of other birds remarkable for their powers of flight or for their beauty. In parts of South America the natives tell you that the gorgeous butterflies called *Morphos* which are only seen high up among the trees on dying enter the ground and there become preserved as emeralds. Flying creatures, especially birds, butterflies, winged mammals and winged serpents, are familiar subjects for more or less conventionalized designs, especially on pottery and totem poles, and coats of arms, but more or less on all ornamented objects and on all types of family or individual insignia.

Of all known kinds of animals almost two thirds can fly, or at least glide through the air, and of land-living creatures the flying sorts number about three quarters of the whole. There are more than 300,000 kinds of flying insects, more than 20,000 flying birds, 600 flying mammals, all but a few of which are bats, possibly 60 flying fishes, and a few flying lizards, snakes and molluscs and perhaps frogs and crustaceans.

Of flying creatures some will fly only at rare intervals and under strong compulsion, and others, like the flying ants and termites, while strong fliers, make only a single flight, after which they discard their wings by cutting them off with their mandibles or by breaking them off at a line of special weakness and again

become ground living. From such as these the amount of time spent on the wing by animals increases step by step until we reach the chimney swifts which fly practically throughout the daylight hours, the insect-eating bats which seem to fly most, if not all, the night, and the albatrosses and related sea-birds which in some localities appear to fly for days and nights together without rest.

The birds are the most familiar of the larger flying creatures. Flying birds range in size from the smallest humming-birds, which are much smaller than our common North American kinds, to the South American condor, with very broad wings, and the wandering albatross with very narrow wings spreading eleven feet or more.

It is a curious fact that the larger the animal the smaller in proportion are the wings. Insects have relatively much larger wings than birds, and small birds have relatively much larger wings than big ones. In the mosquito for each pound of body weight there is a wing area of 4 square yards, 6 square feet, and 105 square inches; in a butterfly of average size each pound of body weight represents a wing area of 3 square yards, 8 square feet, and 87 square inches; in the swallow this is reduced to only 4 square feet and 18 square inches, in the pigeon to 1 square foot and 14 square inches, and in the stork to only 122 square inches.

Not only do the small birds have larger wings than bigger ones, but they move them much more rapidly. The wings of the smaller humming-birds vibrate so fast that it is difficult for the eye to follow them. The wing beats of the sparrow are 780 per minute, of the duck 540, of the pigeon 480 and of the crow about 120.

It was the necessity of finding answers to these questions, why do small birds have to have larger wings than big ones, and why do they have to move their larger wings more rapidly, that made the development of the flying-machine so difficult. The wings of many of the larger birds like the loons and grebes as we see them in the air look ridiculously small, yet these birds can fly for enormous distances at a high speed. It is, however, very difficult for them to get started, and many of them can not rise from the ground at all.

Birds' wings perform two functions: they lift the bird and they drag it forward. We all know that if a light object is thrown it will not travel so far as a heavier object thrown at the same speed. A pitcher can not throw a ball of feathers so far as he can a baseball. If a large and heavy bird can once get going at good speed a relatively small force will keep him going. His body is inclined in such a way that it is kept in the air through its momentum on the principle of a kite. The wings by their motion serve to maintain the speed, but have very little lifting to do. The lighter and smaller

the bird the less is its momentum. Lessened momentum prevents it from maintaining its height by inclining its body against the air. If the wings cease their action the body drops almost instantly. A small bird can approach a perch at full speed and alight upon it with very little voluntary checking of its momentum, but a heavy bird must expend much energy in checking its forward impetus before it can alight with safety. The wings of large and heavy birds serve chiefly to maintain speed, the height being maintained by the momentum and the kiting effect of the body upon the air. The wings of small and light birds must constantly lift as well as maintain momentum—or rather they must constantly lift the bird and pull it forward. This is the reason why the larger the bird the smaller the wings; but the large birds, while they fly with much less effort than the small birds in spite of their smaller wings, have great difficulty in getting started and in stopping. From this it naturally follows that while small birds are found everywhere in all situations, large strong flying birds are mostly confined to the sea and to very open regions where they can arise and alight with safety.

The speed at which birds fly varies very much, but it is not so great as is commonly supposed. You can easily prove this for yourself by pacing them in an automobile along a country road. Only a few birds can fly as fast as the fastest express trains, and none can go so fast as the speedier aeroplanes. Wild ducks and geese have been found to travel on their migrations at a rate of between 44 and 48 miles an hour. Homing pigeons usually travel at between 50 and 55 miles an hour. While some swifts may attain a speed as great as 100 miles an hour, most of our smaller birds fly at a rate of between 25 and 28 miles an hour, or at about the average speed maintained by an automobile.

The power of flight and the possibility of moving rapidly from place to place high above such obstacles as water, trees, fences, hills, etc., permits the birds to wander about from season to season, visiting now one region now another in search of food. In the autumn many of our common birds, like the swifts, the swallows, the flycatchers and the warblers, disappear to the southward, and other birds from the north, like the northern chickadees and nuthatches, the crossbills and the pine and evening grosbeaks, appear in the places they have left. Some birds, like the robin, do not go very far, wintering chiefly in the southern states. Many go to Central and South America, while a few travel enormous distances. The golden plover, which nests in the extreme north of North America, winters in the south of South America. This bird after leaving Labrador ordinarily does not come down again until it arrives at

Guiana, more than 1,700 miles away. It is frequently seen passing over the easternmost of the West Indies at an immense height and has also been seen high in air several hundred miles east of the Bermudas. Coming north it takes a different route, up the Mississippi valley. The eastern godwit, a plover-like bird which nests in Alaska and in eastern Siberia, spends the winter in New Zealand. A great many apparently feeble birds can cover enormous distances without alighting. The little sora rail can cross the Caribbean Sea twice a year without difficulty, and two sorts of cuckoos pass every year from New Zealand to New Caledonia and back over 1,000 miles of sea. In many places it is still erroneously believed that the small birds get about by simply perching on the backs of larger birds and being carried by them, so incredible do such powers of flight appear in such weak creatures.

The height at which birds migrate varies considerably. From measurements taken on birds as they crossed the face of the moon at night it was found that the migrations in May were at a height of from 1,200 to 2,400 feet, and those in October at between 1,400 and 5,400 feet.

The flight of birds may be roughly divided into three types, ordinary flight, with almost innumerable variations, such as we see in the common land birds, soaring and gliding.

In the usual type of flight the bird moves through the air with a continual motion of the wings. This is the only type of flight possible in still air, and is characteristic of most land birds, all the smaller sea birds, the ducks, geese, herons and many others.

The large birds progress ordinarily in a straight line, with a slight raising and lowering of the body at every wing beat if the flight is slow, as in the herons. Their momentum and the kite-like effect of their heavy bodies tend to keep them up, and they are very careful not to lose altitude on account of the great difficulty they experience in rising again. Most of the small birds have a wavy or undulating flight which is especially well seen in the finches and the woodpeckers. The rapidity with which they descend when the wing beats cease shows how slight their momentum is, and how essential for them is the great development of lifting power.

Very many of the larger broad-winged birds, as hawks, eagles, vultures, ravens, pelicans, herons, cranes, spoonbills, screamers, etc., are able to circle on motionless wings, gradually rising higher and higher, until they almost or quite disappear. These birds are large and heavy, and compared with small birds their wing area is relatively less. How do they do it?

Birds seldom soar in cloudy weather, nor in cold regions, nor in the winter. Soaring is only possible when the earth is heated by

the sun's rays. When the earth is heated the warm air just above it rises, and if the heating is intense and long continued, strong columns of air rise for very considerable distances, especially over small hills. In these ascending columns of air the birds find a breeze of considerable strength blowing directly upward, the force of the ascending air being sufficient not only to keep them up but to enable them to glide continually downward, yet at the same time rise.

Birds soar in circles in order to keep within the ascending column of air; if they fall over the edge of the column they begin to flap in order to get back into it again. You sometimes see a hawk do this. Soaring is a very popular pastime of the large birds in the drier regions of the tropics, and in some places, as in Egypt, hundreds of birds of many sorts may frequently be seen soaring together. One of the most expert of the soaring birds is the great clumsy-looking adjutant of India, which by many is supposed to sleep while soaring. In the warm regions the appearance of clouds which obscure the sun promptly weakens the force of the ascending columns of air and soon causes all the soaring birds to flap and to return to the ground. With us in the north only a few birds, mostly eagles, hawks and vultures, soar, and these only on warm, bright and sunny days.

Many birds, such as partridges, pheasants, quail, tinamous, etc., when startled fly diagonally upward with great violence to a considerable height and then glide downward to a place of safety, and most of the larger birds glide more or less when approaching the ground or a perch. This gliding has been developed not only in the direction of soaring as just described, but also into a combination of gliding and soaring—mostly gliding—which is characteristic of the flight of a very large number of sea birds. Many of these are such adepts that they can glide all day and never flap their wings. The albatross is the most marvellous of all the gliders; he courses back and forth over the waves, always keeping close to the water, for hour after hour with his long narrow wings extended almost motionless.

Waves are rows of little hills stretching across the wind. The wind on striking one of these rows of hills is deflected upward with considerable force, and it is by taking advantage of these strong updraughts that the albatross is able to glide perpetually. When flying with the wind the albatross rapidly loses altitude, so he must frequently turn back into the wind again to allow the updraughts from a few waves to raise him anew to the required height. His course to leeward, or down the wind, is therefore a series of loops with long gliding intervals between, and his course across the wind

is a similar series of loops. As a steamer plows its way along, the air behind it is drawn under the stern with such force as to rise into a column of considerable height just behind it. On this column the albatrosses frequently balance themselves, appearing perfectly motionless except for the movement of their heads, traveling at the same rate as the ship, being kept up and drawn along through power originating in the engines of the ship itself. Other sea birds, especially gulls, are fond of balancing themselves on this air column.

In a dead calm the albatross is a pitiable object. He sits on the water, rarely attempting to fly. He can only rise with the greatest difficulty after a prodigious amount of splashing and flapping, and his very slow, heavy and laborious progress is by an alternation of clumsy flapping and gliding, suggesting the flight of an awkward lazy pelican, of which he soon tires; in fact he is all but helpless. The albatross, the most wonderful flier among the birds, is kept in the air not by any efforts of his own, but by a combination of strong wind and waves, and hence the albatross is exclusively a bird of the windier regions of the oceans. He can only exist where the wind is always strong and the waves are always high. The calm belts of the tropics form an impassable barrier for him, and he can not fly for any appreciable distance over land. The stormy southern oceans and the equally boisterous north Pacific are his home; but no one kind exists in both these places. He can not live in the tropic calms, nor in the relatively calm North Atlantic.

Quite a number of smaller sea birds ranging in size from the giant fulmars down to the smaller shearwaters have the same habit of flight as the albatross and are quite as good fliers as is he; but for the most part they are much smaller with broader wings and can fly well in winds so light that they would not serve the albatross at all, and they can also fly well, though with much flapping, during calms. When a strong wind strikes a cliff a considerable amount of air is deflected upward forming a column or wall of air for a considerable height above the top of the cliff. Such a mass of rising air is a favorite playground for birds which soar above it just as other birds do in the columns of warm air rising from the hot tropical lowlands.

At Agattu Island in the western Aleutians where the sun very rarely shines—there is no record that any one ever saw the sun there—but where the wind always blows there is a cliff near the anchorage on and near which all sorts of birds abound. When the wind blows against this cliff the air above it becomes filled with birds, some merely flying back and forth, like the puffins, murres and guillemots, but others wheeling and soaring like hawks. Most con-

spicuous among these soaring birds are the geese, cormorants and ravens, birds which ordinarily we never think of as indulging in diversions of this nature. The gulls, too, are very numerous, but as the gull is an expert balancer and glider it seems only natural that he should be here.

In mountainous regions there are always strong updraughts of air, both because of the upward deflection of the winds and because of the warming action of the sun's rays. Mountainous regions therefore are especially adapted to the development of the soaring habit. The uprush of air due to deflection of the winds makes soaring possible on cloudy days, and in the far north and south under conditions which would prevent it on flat land where the only updraughts are the result of heating.

Mountainous regions always harbor many soaring birds. As a fruit-eating bird would derive no advantage whatever from the practice of soaring, all fruit being far more visible from below or from the side than from above, and also stationary, the soaring birds of mountainous regions are mostly predaceous or carrion feeders, or a combination of the two, or quite omnivorous. They include eagles, vultures, hawks and ravens, and because of the great advantage that they have in being able with a minimum of exertion to survey a vast amount of territory and thus to detect a maximum amount of food, the largest of the flying birds, such as the condor, the Californian vulture, the lammergeier, the griffon and brown vultures, all the larger eagles and the ravens, live in mountainous lands. The buoyant effect of wind blowing against a hillside is easily appreciated by watching a turkey buzzard quartering back and forth in his peculiar seesawing way without flapping his wings, yet without losing altitude.

Among the birds we find all possible gradations from birds like the albatrosses, frigate-birds and chimney swifts, which are almost always on the wing, through the majority of flying birds to such forms as the tinamous and rails, which very seldom fly, to others, like the ostriches, that can not fly at all, and finally to those queer fossil birds with no trace of wings whatever.

The flightless birds fall into three categories: Birds large, powerful or swift enough to outfight or to outdistance any enemies, like the ostriches of Africa and Arabia, the rheas of South America, the emus of Australia and the cassowaries of Queensland, New Guinea and the Moluccas; sea birds frequenting regions where there are no beasts of prey, like the penguins, the great auk and the flightless cormorants of the Commander Islands and the Galapagos; and land birds living in regions from which predaceous beasts are absent, such as the dodo of Mauritius, the solitaire of

Rodriguez, the kiwis of New Zealand, the flightless rails of Oceania, etc. Unless protected by most rigid laws such birds are doomed whenever man penetrates their territory; if large they and their eggs are eaten, and if small they soon become the victims of the dogs, cats and rats which man always carries with him in his wanderings. Thus the Commander Island flightless cormorant, the dodo and the solitaire and the great auk have disappeared, and some of the other flightless birds are much reduced in numbers.

The penguins of the southern hemisphere and the great auk have their wings so modified as to form long and powerful fins with which they swim, after the manner of sea turtles and contrary to the habit of most water birds which swim with their feet only, the wings being used but little if at all. The rheas are peculiar in sometimes running with one wing raised like a sail, no one knows why. The ostriches flap both wings in running more or less. In the emus, cassowaries and kiwis the wings are extremely small.

The ducks, geese, swans and flamingos for part of the year are flightless, for when they moult all their wing feathers are lost at the same time, not one by one as in the case of other birds, and they can not fly until these grow out again. But as these birds are inhabitants of vast marshes, swamps, lakes, isolated reefs and islets, or remote regions where their enemies can not follow them they do not suffer from the temporary loss of flight.

The bats vary much less in bodily form and in the shape of their wings than do the birds, and their flight is much more uniform. None of them soar, and none of them glide. Unlike birds, most of them are all but helpless on the ground, though a few of the small ones can run almost as rapidly as mice. Certain of the smaller bats with long and very narrow wings fly so much like chimney swifts that they are easily mistaken for them, and the resemblance is heightened by their somewhat similar chatter. The largest bats, the flying-foxes and other fruit bats fly like crows.

Nearly all bats, though not rapid fliers, are wonderfully quick on the wing, twisting and turning and even doubling in their flight with an agility rarely seen in birds. For most of them the object of their flight is the same—to enable them to capture insects. Some of them, all large slow-flying ones, eat fruit, one, also large and slow-flying, catches fish, while a few others catch small birds or suck the blood of the larger animals. But the great majority feed on insects, and so the same style of flight is equally suitable for all and there is no need for them to specialize as the birds have done. Soaring and gliding would be of no advantage to the bats, for they must seek their food in those still and quiet regions where night insects fly the thickest; ability to turn quickly is their chief require-

ment. Most bats fly between 10 and 20 feet above the ground, high enough to avoid the bushy and herbaceous growths, and low enough to bring them within the region most frequented by night-flying moths and beetles. They avoid the forests, but are abundant in clearings, in open glades, and on the borders of woodlands. The large fish-eating bats fly just above the surface of the sea like petrels, coursing back and forth in their search for small fishes. In the daytime the bats mostly retreat to the dark recesses of caves or hollow trees, or enter barns or houses, though some of them, like the flying-foxes, suspend themselves from the limbs of trees. Their enemies are few; they are sometimes caught by hawks and owls, and a few small hawks mainly feed upon them.

In the past there lived numerous reptiles with bat-like wings called pterodactyls. These were of a great variety of sizes, from smaller than a sparrow to huge creatures with a spread of twenty feet or more. Their long jaws were armed with formidable teeth, and they must have been very uncomfortable creatures to encounter.

All the remaining sorts of flying animals except the insects are gliders with the surface of the body increased in various ways so that they are able greatly to prolong their leaps by supporting themselves upon the air. Except for the fishes these are all climbing animals inhabiting the forests, and except for the reptiles they are active only at night. The reason for this is that in order to glide successfully they must attain a considerable height, and during a long glide they are practically helpless; they can not dodge about and twist and turn as do the birds and bats, so that if they came out in daylight they would run great danger from the hawks.

One of our very common animals, though one not often noticed because of its strictly nocturnal habits and on account of its small size is the little flying squirrel. Flying squirrels live everywhere in northern forests, in North America, in Europe and in Asia, and in the East Indies some are found which are almost as large as cats.

In the flying squirrels the skin along the sides of the body is extended outward in a broad flap stretching from the fore to the hind legs and supported by a long bone arising from the base of the hand, and the tail is flattened and very dense instead of rounded and loose as in the other squirrels. Supported by these strips of skin the flying squirrels are enabled to make enormous leaps from tree to tree, covering sometimes as much as one hundred feet; but on the ground they are clumsy and awkward.

Our flying squirrels are so retiring and so small that in many of the places where they are commonest only a very few people know of their existence. They spend the day in holes in trees from

which they emerge only after sunset. But they are rather sensitive, and they usually may be frightened out of their holes by tapping the trunk of the tree in which they live. However, it is one thing to get a flying squirrel out into the open, and quite another thing to catch him. He comes from his hole like a flash, climbs to the top of the tree, keeping the trunk between himself and the observer, and launches out into the air. At first he falls diagonally and usually quite abruptly downward, his course gradually curving outward until his body is parallel with the ground, when he suddenly shoots upward and lands on the trunk of another tree, instantly disappearing around the trunk and mounting to the upper branches either to hide or to launch forth again. He is an expert in the art of keeping a tree between himself and his pursuer, and because of the difference in color between the upper and under sides of his body he sometimes seems in the mottled shadows of the woods to disappear while in full flight. As he is not very much larger than a mouse he can hide very easily, and altogether he is quite an elusive creature.

In the forests of the East Indies there lives the flying maki, or *Galeopithecus,* an animal very different from the flying squirrel, but resembling it in its gliding flight. The parachute like extensions of its skin are relatively larger than those of any other gliding animal, and it is able to "fly" for more than two hundred feet. New Guinea and Australia, especially New South Wales, are the home of the flying opossums, some of which are among the smallest of all known mammals, measuring scarcely five and a half inches in length with the tail making up more than half of this. These little creatures are more expert on the wing than the flying squirrels or the flying maki, and are able to twist and turn to an astonishing degree. The great forests south of the Sahara are inhabited by the flying mouse, a little creature with the habits of the flying opossums.

In the East Indian region are found the flying lizards. These are rather small lizards with a broad thin semicircular projection like a broad fin stiffened by processes from the ribs on either side of the body by means of which they are enabled to glide through the air after the manner of the flying squirrels. Like the flying squirrels they glide obliquely downward until near their objective, when they turn and finish their flight with a short upward glide. Some of the Malayan geckos or singing lizards have the body expanded somewhat after the fashion of the flying lizards, but the expansion is not stiffened. These have been supposed to fly, but Dr. Stejneger believes that the broadening is merely an adaptation for concealing them by obscuring their outline and that they can not really fly.

Certain climbing snakes of the Malayan archipelago are able without any special adaptations of the body to glide through the air like a missile from one tree to another over a considerable distance. These flying snakes have the under side of the body marked with deep longitudinal grooves, and during the leap they hold themselves motionless like a rigid stick.

In the forests of Sumatra, Borneo and Java there lives the flying frog, a sort of tree frog with especially elongate toes and fingers between which are greatly developed webs. In jumping from tree to tree this frog is said to spread its feet and thus to glide on the expanded membranes much after the manner of the flying squirrels, covering enormous distances. Most tree frogs are prodigious jumpers, and there seems to be some doubt whether this one is really helped much by its large feet.

We all know that certain kinds of animals are only found in certain regions of the world, tigers only in Asia, giraffes and zebras only in Africa, kangaroos only in Australia, musk oxen only in the arctic regions, armadillos and sloths only in tropical America, etc. In the same way certain habits affecting many kinds of animals may be confined to particular localities. Terrestrial flying creatures other than insects, birds and bats are almost exclusively confined to the East Indian region, where we find flying squirrels, flying makis, flying lizards, flying snakes and flying frogs. Outside of the East Indies there are only three types of flying animals, the flying squirrels of Asia, Europe and North America, the flying opossums of Australia and New Guinea, and the flying mice of Africa, only one sort of flying creature in each place. Except for birds and bats and insects there are no flying animals of any kind in South America.

But on the other hand the habit of hanging by the tail and of using the tail as an organ of prehension and of locomotion is almost exclusively confined to tropical America, where it is characteristic of many animals in many very diverse groups, as monkeys, carnivorous animals, opossums, rats and porcupines. Why should this be so?

Let us now briefly survey the insects, the most numerous of all the flying creatures. In their younger stages all insects are wingless, but when adult most insects can fly. Of all of them the tsetses and some of the bird flies fly the longest in proportion to their length of life. These flies are born as pupae or as larvae just ready to transform to pupae from which adults emerge. They do not feed as larvae or as pupae, and their adult winged existence is correspondingly prolonged.

In many insects the flying stage is very short. For instance the seventeen year locust, or "periodical cicada" as the entomolo-

gists would prefer to have us call it, spends only about one nine hundredth part of its existence in the winged state, and it does not fly much even in that short time; while in some may-flies, which lack a mouth and therefore can not feed, the flying period is less than one one thousandth part of their whole life. Thus if we were may-flies flying would be possible for not more than twenty-five days out of a normal life. In most insects the flying stage is rather short compared with the whole length of life, and in very few is it so much as a quarter of their whole existence. In most flying insects both sexes fly equally well, as among the birds and bats, but in many the larger and heavier females are much less expert than the males, and in some the females can not fly at all, the wings being much reduced in size or even absent altogether.

Let us here repeat that the relative size of an insect's wing is much greater than that of a bird's wing. An insect is so light that it has no momentum, so that the wings must continually pull the body forward as well as lift it. Since there is no momentum the lifting and the pulling must be as nearly continuous as possible, so that the wing motion of insects is incomparably more rapid than that of birds. The common cabbage butterfly moves its wings at the rate of 540 strokes per minute; the sphingid moths at the rate of 4,320 beats per minute; the wasp at the rate of 6,600 beats per minute; the honey bee at the rate of 11,400 beats per minute; while the wings of the common house-fly vibrate at the rate of 19,800 beats per minute.

The difference in the relative area of the wings between a mosquito and a stork may be appreciated when it is realized that if a stork had wings proportionately as large as those of a mosquito they would have an area of almost twenty-eight and a half square yards, and an expanse of more than twenty-five feet.

Of all the insects the larger dragon-flies, so common about the ponds and streams in which they live when young, are the swiftest on the wing. One sort of these (*Austrophlebia*) was timed by Dr. R. J. Tillyard, who found that it covered between 80 and 90 yards in three seconds, which means that it was flying at the rate of nearly 60 miles an hour.

Dr. Alexander Wetmore has recently determined that the great blue heron flies at the rate of 28 miles an hour, the red-tailed hawk at 22, the flicker at 25, and the raven at 24, so it is evident that the larger dragon-flies have little to fear from birds, though many of the smaller, weaker ones are eaten by them. Such birds as travel at a rate approaching that of the large dragon-flies often become victims of their speed. Being heavy, they can not turn aside to avoid danger; put a net suddenly in front of them, and into it they go.

The Esquimaux catch thousands of sea-birds annually in this way by intercepting them as they fly along the shore. But the dragon-fly is different. Put a net in front of him and he instantly shoots off sideways, or up or down, or even doubles on his course. He is so light that he has no appreciable momentum and therefore he can twist and turn about in a way quite impossible for any bird.

There are many different kinds of dragon-flies; all of them eat other insects which they catch upon the wing. They have many different kinds of flight, darting, skimming or soaring about in search of their more or less nimble victims. But the soaring, so-called, of a dragon-fly is a very different thing from the soaring of a bird; at first sight it seems to be the same, but if you watch closely you will see that the dragon-fly keeps his wings in motion almost all the time.

Dragon-flies have various relatives, like ant-lions and lace-winged flies, which, strange to say, are slow and feeble fliers; they are awkward and clumsy in the air and they give you the impression that their wings are too big for them.

The dragon-flies and their relatives are the only flying creatures which have two functional pairs of wings acting independently and placed one behind the other as in the original Langley aeroplane.

The beetles, like the dragon-fly, have two independent pairs of wings, but the wings of the anterior pair are modified in such a way that when the beetle is at rest they fit closely down over those of the posterior pair, which are folded up beneath them. In flight these anterior wings are held rigidly extended at various angles, the hinder wings doing all the work. It is possible, however, that in some cases the anterior wings may serve the purpose of a pair of planes, assisting in keeping the insect in the air, though many beetles fly just as well if they are removed, and in some excellent fliers, like the devil's coach horse, they are so small as to be quite functionless.

As a rule the flight of beetles is slow and clumsy, especially of the larger kinds which fly only at night and rather high so as to avoid the shrubs and bushes. Some, like the tiger beetles which in the spring we see running rapidly about on the bare ground in their hunt for smaller insects, are quite expert in turning and twisting in the air, while very many can not fly at all.

The grasshoppers, locusts, crickets and their allies have the fore wings stiff and tough, not used in flight, and the hind wings membranous and closing like a fan instead of being folded on a hinge in the front margin as in the beetles. In most the flight is weak and rattly, and very many can not fly at all. But some, like the migratory locusts, are strong fliers.

Regarding the speed of grasshoppers I quote a letter from Mr. Andrew N. Caudell:

> In early August of 1920 while studying economic species of grasshoppers in Centennial Valley, Montana, I had an excellent opportunity of observing the speed at which *Cannula pellucida* flew. By noting individuals that were flushed by the roadside by the automobile in which I was riding I chose ones that flew parallel with the machine, which was driven at the rate of 15 miles per hour. I found that under those conditions the rate of flight for this species is almost exactly 15 miles per hour. In long flights, especially with the wind, the rate may be much faster, as J. R. Parker has estimated the speed of migratory swarms to be 30 miles per hour. That appears to be too high an estimate, judging from my experience with the insects' flight when flushed by the automobile. Mr. C. L. Corkins gives the rate of flight of *Melanoplus atlantis* as 20 miles per hour, the rate being determined by the same method I used with *Cannula,* that is by observations made from an automobile moving at a given rate.

The flies properly so called, the house-fly, the blue-bottle, the horse-fly, the crane-fly, the black-fly, the mosquito, the gnat, the midge, the robber-fly, etc., have only two wings, the hinder pair being replaced by curious knobbed structures known as balancers or halters which are apparently sensory and in some kinds possibly stridulating. It is interesting to note that while in the beetles the hind wings only are used for flight, in the flies these have completely lost their function as flying organs, the flight being effected entirely by those of the anterior pair.

While a few flies are wingless, or have very small and useless wings, most of them are expert fliers. They can twist and turn and dodge and hover and dart quite as well as the dragon-flies, and though most of them are not very speedy, some, like the robber-flies which feed on other insects, are by no means slow. There are more different kinds of flight among the flies than among any other kinds of insects, ranging from the direct, swift and powerful flight of the robber and horse-flies and the twisting and dodging flight of the lesser house fly to the dancing of the gnats and the hovering and darting of many syrphids and bombyliids. These last are commonly seen suspended and apparently motionless in the air a few feet above the ground over woodland paths; if startled they dodge away so rapidly that frequently the eye can not follow them.

In most other insects the four wings when extended function as a single pair, the hinder edge of the fore wings being hooked to the front edge of the hind wings in various ways, as in the butterflies, moths, bees, wasps, etc. In some of the butterflies and moths the wings are enormous in proportion to the size of the body.

Very few insects have a definitely developed tail capable of being used for steering; some of the hawk moths have movable tufts of long hairs on the end of the body which may be used for this

purpose, and one of the small parasitic wasps has a very remarkable tail of two thin plates crossing each other at right angles in the middle. Many butterflies, like the swallow-tails, and a number of moths, like our common luna and its various Asiatic relatives, have the hind wings produced into so-called tails, which may be very long; in some species only the males have them. In other insects, as in certain ant-lions, the fore wings may be normal, but the hind wings are very narrow and extremely long and more or less twisted.

In all flying animals the steering is done chiefly or entirely with the wings. Many bats are tailless, but they fly quite as well as the bats with tails. The long-tailed birds, like the cuckoos, forked-tailed, scissor-tailed and paradise fly-catchers, long-tailed trogons, tailor birds, emu wrens, lyre birds, turkeys, curassows, pheasants, etc., are relatively weak fliers, while all the birds remarkable for very long flights, like the plovers, curlews, godwits, ducks, geese and swans, or for long-continued gliding flight, like albatrosses and shearwaters, are short-tailed. Soaring birds to increase the lifting surface mostly have large broad tails, just as they have very broad wings. Most long-tailed birds are small; if large they are ground living; if good fliers the elongated feathers of the tail are reduced to two which are usually very narrow, the two outermost in the swallows, terns, some flycatchers, some humming-birds, etc., the two central in the macaws, lories, tropic-birds, other flycatchers, other humming-birds, etc. Birds which pounce upon their prey or feed after the manner of bats, such as most hawks, falcons, kites and owls, goatsuckers, night-hawks, whippoorwills, most flycatchers, etc., have large broad tails, and undoubtedly these assist them in turning abruptly downward, upward or sideways.

Most creatures when flying make more or less noise, and many have special sounding organs connected with their wings. The bats all make a low swishing sound which is only audible for a short distance. The wings of most birds make a swishing sound which varies from the droning hum of the humming-birds to the loud dull rustling roar of the large vultures, swans, geese and ducks. These sounds are merely the result of the rapid passage of the wings through the air. In some ducks, on that account commonly called "whistlers," the wings make a loud shrill whistling noise in flight which on a still day may be heard for a very considerable distance; this is due to the vibration set in motion by parts of certain of the wing feathers. The passage of most pigeons and doves and of some other rapid fliers through the air is also accompanied by a more or less distinct whistling. In addition to this pigeons and doves on rising suddenly from the ground usually make a clapping or rattling noise with their wings; but if not startled they often rise

quietly. The flight of some birds, especially of the owls, is strangely silent, apparently so as not to interfere with the detection of the slight sounds made by the creatures they are seeking, by which means they find them.

The droning of beetles and the buzzing and humming of flies, bees, wasps, mosquitoes, etc., are known to every one; some insects, like the large cockroaches in the tropics, fly with a loud rattling noise, and some, like certain butterflies and grasshoppers, when on the wing make chirping or clicking sounds at will by means of a special mechanism connected with the wings.

The flight of the large slow-flying moths, like our common cecropia, polyphemus, promethea and luna, like that of the owls, is almost noiseless; and it is fortunate for them that this is so as otherwise they would soon disappear through extermination by the small owls and by the bats.

Many flies can hum or buzz quite as well with the wings cut off as with them present, apparently through the action of the halteres which in this case appear to be wings transformed into singing organs. The song of the crickets, locusts, grasshoppers, katydids and similar insects is produced by the forewings, parts of which are modified into very perfect sounding organs operated by the rubbing of the wings together or by the long hind legs.

The song of the cicadas and their allies, though it sounds much like that of the crickets and the locusts, at least like that of some of their tropical representatives, is not produced by the wings but by a special apparatus on the under side of the body. In some kinds the piercing shriek they give can only be compared to the whistle of a steam engine, and may easily be heard on a calm day four miles or more.

The wings of insects are mere outgrowths from the body wall, quite unconnected with the legs. They are thus comparable to the side extensions of the flying lizards and to the cobra's hood. In many groups, especially in the moths and butterflies and in many flies, like moth-flies, they bear numerous broad scales somewhat resembling the feathers of a bird; in others they are often sparsely hairy like a bat's wings.

Except for bats all the flying mammals are tree-living climbing creatures, and in them the wing membrane is stretched between the legs. In the bats and birds the wings are an adaptation from special climbing organs, somewhat as suggested by the long arms of the spider monkeys. In the bats the flying surface is formed by broad areas of skin stretched between immensely elongated fingers and extending to the hind legs as in the ancient flying reptiles and in all other flying mammals. In the birds the flying surface is

made up of long feathers which are outgrowths of the skin of the long front limbs. With their very long arms the monkeys and the lemurs climb with great rapidity through the forest trees. With their very strong and suitably modified front limbs the bats and birds in much the same way climb through the air. One bird, the hoactzin, when young climbs actively about the bushes with its fore limbs which, as in many other birds, have claws; when fully grown it climbs through the air like any other bird.

The wings of flying fishes do not differ from the corresponding fins of other fishes except in their greater size.

Besides the animals which fly by their own efforts there are many others which at some period of their existence, usually when young, are wafted through the air without the aid of flying organs just as the seeds of many plants are blown about.

Chief among these are the flying spiders. Many different kinds of spiders have hit upon this means of getting from place to place. It is usually, though not invariably, the young spiders that do this, and the phenomenon is best observed on warm and comparatively quiet autumn days when there is a good updraught of wind. The spiders climb to the summit of some object, such as a stick, fence post, plant or stone, and release a fine thread or several of them, or sometimes a tangled mass of threads. When the pull of the ascending air upon the threads is strong enough the spider lets go his hold and floats away. One of the most sedentary of the spiders, living as a rule under stones, sticks and other objects, has adopted this means of getting from place to place, and it is also used by spiders of many other kinds. Occasionally spiders try to rise in an adverse wind, and then their threads instead of rising are blown onto the ground or onto the nearby plants sometimes forming enormous sheets of silk. These sheets of silk may later be lifted up and blown away, coming down in some distant place as a so-called gossamer shower.

Many insects, especially the smaller ones like aphids, can fly just well enough to keep up in the air without making much of any progress. These form a connecting link between creatures that fly by their own efforts and those that are wafted by the winds from place to place. Many caterpillars, such as those of the gypsy moth, are when very small widely distributed by the strong winds of spring.

When a pond dries up many of the small water creatures either condense themselves into the smallest possible space and surround themselves with a tough shell, or form highly resistant eggs and die. These capsules and eggs are picked up by the wind and carried for long distances; in fact the air, even for hundreds of miles

at sea, always contains besides mineral dust, particles representing the remains and the living spores and seeds of animals and plants. This is why any puddle of water, no matter where it is, on the ground, on a roof, or in hollows in the branches of tall trees, swarms with life almost immediately after its appearance.

Among the animals on land which do not fly many of the larger ones have certain adaptations which enable them to use the resistance of the air for their protection. Leaping animals that live in tree tops, like the lemurs and the smaller monkeys and most squirrels very often have great outgrowths of long hairs which serve to minimize the shock of landing. The so-called flying-monkey of the upper Amazons looks when it leaps much like a flying squirrel, but it has no extended membranes on its sides, great tufts of long hair simulating these.

The cobras when they strike raise themselves high above the ground on the tail and hinder portion of the body, and then fall forward. They do not shoot the head out suddenly as do our rattlesnakes. As they fall forward their broad hood acts as a wind brake and delays the body so that the danger from the fall is minimized. In the frilled lizard of Australia which runs very rapidly on its hind legs with the body more or less erect the frills act as an air brake in the same way.

We have now considered all the flying animals that live on land; but in addition there are some that live in water. Chief among the aquatic flying creatures are the flying-fishes which are abundant in all the warmer seas. These fishes are one of the great wonders of the oceans. Leaving the water with a tremendous rush, the large side fins, which in some kinds reach a length equal to two thirds the total body length or even more, are rigidly extended like the wings of an aeroplane and held in this position by powerful muscles. Supported by these great fins the fish is able to go for an astonishingly long distance, and in a strong wind to rise to a considerable height. When its momentum is expended it falls back into the water, or sometimes takes a fresh start by the vigorous action of its tail, the lower and larger part of which is dipped beneath the surface.

The old question, which was created first, the hen or the egg, is replaced at sea by the equally old question, do flying-fishes really fly, or do they not? This question is always being discussed somewhere or other and has been under continual discussion ever since man first sailed the seas. Every sailor knows that the wings of flying-fishes move, for he has seen them move and heard them hum; nothing but the fish could move them, and therefore he says that the fish does move them, and consequently flies after the man-

ner of a bird. Others say the flying-fishes do not fly because they can not; the muscles about the base of the wing-like fins, though large and strong, are merely used to keep the fins extended and serve no other purpose. The sailor retorts that this is pure theory and not to be considered in the light of the observed fact that the wings are actually moved. Both sides, the realists and the theorists, support their views with all sorts of arguments from the realms of marine biology, anatomy and marine mythology, and the discussion finally comes to rest exactly where it started. No real sailor will admit that flying-fishes can not fly, while no landsman will admit they can.

In their contentions both are partly right. It has been shown that flying-fishes fly so far that their flight can not be explained on the basis of the original impetus alone; no one who has seen them at close quarters can doubt the movement of their fins. Therefore, while flying-fishes are mainly gliders, their flight to some extent is aided by the movement of their fins. While flying-fishes jump from the water and glide away right and left before a steamer, a small boat does not disturb them in the least. If you are out in a small boat there may be thousands of them about you and you may never learn their presence. Through this peculiarity they are easy to secure.

When the trade wind is blowing the surface of the sea is covered with little waves from which the sunlight is reflected so that a relatively small amount penetrates beneath the surface. While to us the ocean looks especially bright and sparkling in a brisk breeze, beneath the surface it is dark and gloomy, for all the myriads of sparkles that catch our eye mean a corresponding amount of light rebounding from the surface instead of penetrating. It is under these conditions that the fishermen go forth to catch the flying-fish. For this they must go for a long distance, until the shore begins to disappear, for the flying-fish is preeminently a creature of the high seas and well knows the dangers that lurk in shallow water. Having arrived at what he considers a suitable location, the fisherman throws overboard some oily matter, usually, because most available, some half decayed flying-fishes from a previous catch. The oil spreads out and forms a relatively quiet area about the boat; the waves within this cease to sparkle, and the surface here takes on a dark and gloomy aspect. But looked at from below just the reverse occurs; the stilling of the wavelets results in the formation of a brilliantly lighted patch. Though previously no flying-fish at all were visible, the water about the boat now teems with them; they have come from all directions attracted by the bright spot on the surface. With frantic haste they are scooped

into the boat with dip-nets—they do not attempt to fly—until suddenly they all vanish. Immediately several large hooks on strong lines are thrown out, each with a flying-fish as bait, and one or more is often seized by a dolphin or a shark, whatever it was that frightened the flying-fish away. The oil has now become so scattered that its effect is lost, and the fishermen sail away to try their luck elsewhere.

There are three little flying-fishes that live in fresh water, one, the most expert of them, in the rivers of western Africa, and the other two, which are only able to make short flights, in eastern South America. Flying-fishes are no new creation, for as far back as the Triassic seas there were at least three kinds, in some respects much better adapted for flight than are those of the present day.

Brief mention must be made of those so-called flying-fishes that do not fly, chief among which are the flying gurnards. In these fishes the side fins are enormous, and often very brightly colored, and look as if they could be used in flight. But these are sluggish bottom-living fishes found only in shallow water near the shores and more or less like sculpins in their habits. They never leave the water except perhaps and very rarely in a short clumsy jump. The bat-fishes of the tropics, which are enormous rays, like many other fishes will sometimes leap above the surface but they do not fly.

In some parts of the ocean the passage of a steamer will frighten from the water objects which at first sight look like flying-fishes, of about the same size but thinner and more cylindrical. When these things leave the water instead of scattering as does a company of flying-fishes they always keep together in a close formation maintaining the same distance from each other, and all the members of a company always drop into the sea at the same time. I first saw these off northwestern Africa and it was the close formation that attracted my attention. Their flight is rather short, and it was difficult to catch them with the telescope; but when I did I found that they were cuttle-fish or squid, flying tail first, and easily distinguishable from the fishes by their large dark eyes at the wrong end.

The only other flying thing at sea, except the birds, and sometimes bats on their migrations, is a small crustacean that lives in great numbers at the surface in some places. This little creature often jumps clear of the water, and is said to prolong its leap by gliding through the air after the manner of a flying-squirrel.

KELP AS AN AGENT FOR THE CONTROL OF GOITER

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Prevalence and Incidence of Goiter

Goiter is a disease seemingly without historic, geographic, topographic, climatic, racial, genus, sex or age restrictions. It was known to the Greeks at the time of the Greek Empire. To-day it is reported from Asia, New Zealand, Africa, the Near East, the various European countries, North and South America, the United States, from all the states and particularly throughout an area extending in an east to west direction from the New England States to the Pacific Coast and Alaska, thus completing the entire circuit of the globe. It is reported from the tropical islands of Asia to the cold upper valleys of the Himalayas, from Florida to British Columbia, from the seashore to the highest mountains. Among races, it is observed among the negroes of Africa, one extreme, throughout the various races, to the most civilized. It is found likewise among most of the animals retained under those conditions which make observation easily possible (the domestic animals), some of the fowls and even frogs and fish. It finds its victims among both males and females, the young, the middle-aged and the old.

The common impression is that the prevalence among women and girls is about six times that among men and boys. However, it appears that in foci of severe endemic goiter, sex plays little part.[1] Geographically, incidence varies over wide limits, from a very small figure to almost 100 per cent.

The region of greatest endemicity inhabited by a white race is Switzerland. Here the incidence in certain localities is reported as 100 per cent., where it has been attributed to the drinking of "snow water." Klinger[2] reports a specific incidence among a school population of 82 to 95 per cent. Equal prevalence is reported from certain valleys of the Himalayas.

The incidence in the United States reaches 25 per cent. (among females) in a number of instances and covering a large portion of

[1] Hayhurst, "The present-day sources of common salt in relation to health and especially to iodine scarcity and goiter," *J. Am. Med. Assn.*, *78*, 18 (1922).

[2] As quoted by Marine and Kimball, *loc. cit.*

the thickly inhabited regions of the country. The distribution of cases among the men of draft age of various racial, social and industrial classes, the only comprehensive survey made to date, is shown in the following table:[3]

TABLE I
INCIDENCE OF GOITER AMONG DRAFTED MEN

Group	Total cases	Ratio per 1,000	Ratio per 1,000 cases, in groups
Agric., native, white, north, 73 per cent. plus	1,866	9.24	17.46
Agric., foreign and native, white	3,490	11.91	22.61
Agric., native, white, South	1,443	3.36	6.50
Agric., negro, 45 per cent. plus	317	1.76	3.19
Eastern manufacturing	926	4.15	6.98
Commuters	299	4.03	7.49
Mining	1,203	12.57	22.11
Sparsely settled, 3 or less per sq. mi.	747	16.53	28.85
Desert	44	3.64	5.44
Maritime	42	2.09	3.05
Mountain	775	14.70	25.71
Mountain whites	539	7.40	13.04
Indian, sparsely settled	79	2.48	4.68
Mexican, sparsely settled	35	1.26	2.68
Native white, Scotch origin	154	2.84	6.00
Russian, 10 per cent. plus	387	10.18	17.21
Scandinavian, 10 per cent.	2,865	18.25	33.59
Finns, 10 per cent.	364	26.71	51.41
French Canadian, 10 per cent. plus	109	1.18	1.73
German and Scandinavian	1,446	14.66	28.33
German and Austrian, 20 per cent. plus	1,048	10.55	20.63
German and Austrian, 15 per cent. plus	3,747	10.66	19.75

From an examination of available data relating to incidence the following generalizations may be drawn:

(1) Goiter occurs in all parts of the United States, no locality being exempt.

(2) Regions lying close to the Atlantic and Gulf Coasts are relatively free of goiter (low-lying coast lines).

(3) It seems that goiter is a disease preeminently of the Great Lakes region and of the extreme northwest.

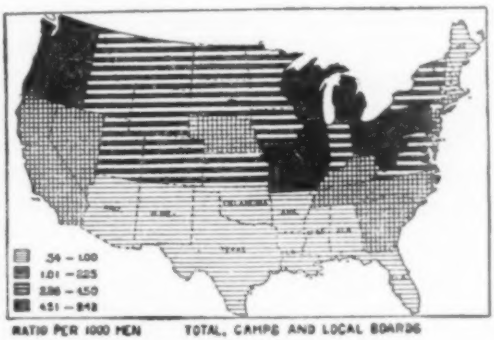
(4) It is almost absent throughout the southern states from the Cape Fear River to the Colorado.

(5) Regions lying near the *tops* of drainage areas show high endemicity (mountain areas, the upper portion of the Mississippi Valley and plateau regions).

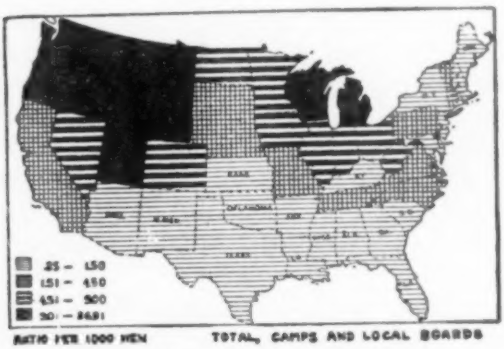
[3] "Defects of drafted men," War Dept. Publication, p. 232.

(6) Regions underlain by the older rock formations show more goiter than those underlain by recently deposited alluvial plains; also regions characterized by thin soils underlain by impervious rocks, both (together with (5) above) connoting thoroughly leached soils.

GOITER, EXOPHTHALMIC



GOITRE, SIMPLE



GOITER MAPS FOR THE UNITED STATES

In considering the goiter maps for the United States, here presented, it should be noted that the endemicities of the two types, simple goiter and exophthalmic goiter, are closely parallel, a coincidence which apparently has hitherto escaped general recognition.

A few specific incidences of certain American localities are reported. Marine and Kimball[4] record that among 2,305 school girls of Akron who were kept under observation for a period of two years, 21 per cent. developed goiter. They mention a maximum incidence of 56 per cent.

[4] "The prevention of simple goiter in man," *J. Am. Med. Assn.*, 77, 1068 (Oct., 1921).

Clark[5] examined 13,836 school children in 11 counties of West Virginia during the fall of 1913 and found 1,234 cases of goiter (8.9 per cent.); and 6,432 public school children in 9 Virginia counties and found 817 cases (12.7 per cent.) of goiter. In other states, notably Ohio, Washington, Montana and Vermont, the incidence among school children is estimated by trained observers without an actual census, as varying from 25 per cent. to 50 per cent.

The endemicity among domestic animals, where reported, coincides in a general way with that among human beings, in many cases being more marked. When it is recalled that in some of the goitrous regions of the northwest, the mortality from this cause among newborn animals, before preventive measures were introduced, was almost 100 per cent., some idea is conveyed of the prevalence of the disease.

The Thyroid Gland

Some statement of the vital rôle played by the thyroid gland in the processes of the animal body is essential to an appreciation of the subject here treated.

A function of the thyroid is to handle the iodine supply of the body. Its high content of iodine has long been known. This is capable of wide variation, from little or none in cases of iodine starvation, to 0.36 mg. per g. of fresh gland under normal conditions. The figure of 0.1 per cent. is taken as the lower normal limit, any amount below that indicating iodine deficiency.

The minute quantity of iodine entering the body and assimilated is taken by the gland, it appears, stored up in its colloids and as requirements dictate is readmitted to the circulation as an organic compound.

In the thyroid colloids, it is recognized, is deposited the reserve store of iodine. It is drawn upon, in the opinion of McCarrison, *only when the daily routine of the body demands a greater quantity of iodine than that regularly supplied by the diet.* "The 'emergency ration' of iodine-containing colloid is, however, called upon when the supply of iodine in the food runs short, under the demands of excessive sympathetic excitation, such as occurs in rage or fright (Cannon), at certain periods of life—dentition, puberty, menstruation, pregnancy or lactation—as a result of residence at high altitudes, at certain seasons of the year, and when the body is invaded by micro-organisms or subject to certain intoxications."[6]

[5] Clark and Pierce, "Endemic goiter," Reprint 184, Public Health Reports, U. S. Public Health Service.

[6] McCarrison, "The Thyroid Gland."

"Apparently man's metabolic welfare depends in part on the maintenance of this seemingly insignificant yet actually indispensable store of iodine."[7]

The function of the thyroid gland may best be described in the words of McCarrison,[8] who lists the principal duties of that gland as four in number:

> (1) It governs the growth of all cells, and sustains their functional activity. (2) It controls calcium metabolism. (3) It is a profound katabolic stimulant, facilitating the breaking down of exhausted cells and governing the elimination of the waste products of their disintegration. (4) It exercises a protective antitoxic and immunizing action, defending the body not only against the toxic products of its own metabolism, but against invasion by disease-producing micro-organisms and injury by their products. . . .
>
> The thyroid gland is to the human body what the draught is to the fire; nay, more; its iodine, by its chemical interaction with certain unknown constituents of the cells, is the match which kindles it. . . .
>
> The thyroid gland is specifically associated in the exercise of its functions with the generative organs. . . . By stimulating the development and growth of the sex organs the thyroid secures through them the progress of mental and physical growth; witness their suppression in cretinism and juvenile myxoedema.

Results of Goiter

In discussing the symptomic results of goiter it is conventional to differentiate between the two general phases of the disease, the so-called simple (adolescent or incipient) goiter and the more advanced, exophthalmic (or toxic) goiter or hyper-thyroidism.

Simple goiter, characteristic of adolescence, manifests itself as an enlargement of the thyroid gland, symmetrical swellings near the base of the neck. It attracts little attention. Under superficial diagnosis this may appear as the only recognized result of the disease. However, this should always be taken as a danger signal since as the other extreme there may ensue a failure on the part of the victim to complete the metamorphosis of adolescence. The puerile characteristics may persist, and the lack of physical development may be accompanied by a lack of mental development.

Congenital goiter is perhaps the worst though a less frequent phase of the disease, as it foredooms the child to a subnormal existence. As a first effect it increases the mortality among newborn infants. If the infants survive they are the victims of physical and mental degeneration, with bodily deformity and mental imbecility, and frequently mutism, deaf-mutism and idiocy—cretinism. Goiter in the mother is the cause of goiter in the unborn child.

Exophthalmic goiter, more common among adults, while frequently accompanied by an enlargement of the thyroid gland, mani-

[7] Ed. *J. Am. Med. Assn.*, *77*, 1574 (1921).

[8] *Loc. cit.*, p. 22.

fests itself rather by a serious derangement of the nervous system, with rapid pulse, especially on excitement, and tremor. It causes a greatly depressed state of health, with loss of flesh, and a general derangement of the functional activities of the body. Protruding eyes (exophthalmos) is a symptom of an advanced stage, and insanity and death may be its culmination.

Or, myxedema may ensue, in which case there is a thickening of the skin and enlargement and coarsening of the features, with dropsical symptoms, a loss of memory and general mental degeneration.

"There are few human beings living under modern conditions of life in whom the [thyroid] gland is wholly normal."[9]

In domestic animals—whose diets may also be arranged in accordance with man's ideas as to what constitutes a proper ration—goiter leads to a high rate of mortality among the newborn, where it exhibits itself as "big neck" among calves, "weakness" in foals ("weak colts"), "hairlessness" among pigs, "weakness" among lambs and "big neck" or "hairlessness" among newborn goats.[10] It also occurs among dogs, cats and chickens.

Cause of Goiter

"The immediate cause [of goiter] is a lack of iodine."[11] Since the presence of certain amounts of iodine in the diet almost invariably prevents its occurrence and in the majority of cases in the early stages of the disease causes its disappearance, as attested by abundant experimental data, this conclusion is substantiated. It is one of the simplest and most thoroughly authenticated instances of a deficiency disease.

Marine[12] found that young fish in a hatchery in Pennsylvania were being exterminated by goiter and promptly eradicated the disease by adding iodine to the water in which they were being maintained.

Halstead showed that if the thyroid of a dog were partly removed the remaining portion would begin to enlarge, and Marine[13] showed that if iodine were administered to the dog under those circumstances the remaining portion of the thyroid would not enlarge. Marine and Lenhart[14] demonstrated that goiter developed in dogs if they were deprived of all iodine, as soon as the iodine content of

[9] McCarrison, *loc. cit.*

[10] Kalkus, "A study of goiter and associated conditions in domestic animals," Bul. 156, Ag. Expt. Sta., State College of Washington.

[11] Marine and Kimball, *loc. cit.*

[12] Bul. 7, Penn. State Fisheries.

[13] *J. Inf. Dis.*, IV, p. 425 (1907).

[14] Arch. Int. Med. *3*, 66 (1909).

the gland, through exhaustion, fell below a certain limiting percentage and conversely that goiter could not be induced where iodine was supplied. Finally, Marine and Kimball[15] in 1917 in their classic demonstration with the school children of Akron, Ohio, showed that the facts established with animals applied in general quite as well to human beings, the most spectacular and fundamental piece of work that has been done in America in connection with this deficiency disease and ranking in importance with the other great basic demonstrations in disease prevention.

Goiter has been ascribed circumstantially by various writers to various causes, many conflicting and contradictory, which can be compromised only on the basis that any set of circumstances which entails extraordinary demands on the thyroid gland will, *when coupled with a deficiency of iodine,* tend to induce goiter. In all the mass of evidence bearing on the subject there seems to be nothing which successfully controverts the statement of Marine and Kimball that if the iodine store in the thyroid be maintained above 0.1 per cent. no hyperplastic changes and therefore no goiter can develop.[16] The cause of goiter seemingly is demonstrated beyond a peradventure.

Iodine as a Preventive and Cure

Dr. Richard Russell in 1752[17] described the use of sea water in the treatment of goiter. The Swiss have long known that an occasional sojourn at the seashore would result in practical immunity, an expedient restricted to the well-to-do. Since the work of Coindet (1820) the value of iodine in the treatment of goiter has been on record. The eradication of goiter among fish by administering iodine has been demonstrated by Marine[18] in 1910, and Gaylord and Marsh[19] in 1914; among animals by Marine and Lenhart,[20] Smith,[21] Hart and Steenbock,[22] Welch[23] and Kalkus.[24]

In America the first large-scale application of preventive and curative measures to human beings was the demonstration by Marine and Kimball with the school children of Akron in 1917,[25]

15 *Loc. cit.*

16 "The prevention of simple goiter in man," *loc. cit.*

17 "The Use of Sea Water in the Treatment of Glandular Diseases."

18 Bul. 7, Dept. Fisheries, State of Penn.

19 Bul. 32, U. S. Bureau of Fisheries.

20 *Loc. cit.; cf.* also *J. Exp. Med., 19,* 70 (1914).

21 *J. Biol. Chem., 29,* 215 (1920).

22 Bul. 297, Agr. Exp. Sta. Univ. of Wis.

23 Bul. 119, Ag. Exp. Sta. Univ. of Montana, "Hairlessness and goiter in newborn domestic animals."

24 Bul. 156, State Col. of Wy., Ag. Exp. Sta., "A study of goiter and associated conditions in domestic animals" (1920).

25 "The prevention of simple goiter in man," *loc. cit.*

referred to above, in which some 4,500 children were placed under observation. These were divided into two groups: to the first, 2,190 in number, iodine was administered, of which number only 5 developed goiter, while among the second group, 2,305 in number, who did not take the treatment, 495 developed goiter (0.2 per cent. *vs.* 21 per cent.)—a demonstration of the preventive efficacy of iodine of the most convincing sort. Furthermore, as to the curative power of iodine, it was shown that of 1,182 pupils with thyroid enlargements at the beginning, 773 (65 per cent.) showed a reduction as a result of the treatment.

Klinger (1921), in experimentation with the school children of Zurich, where the incidence was 82–95 per cent., showed curative effects in 73 per cent. of cases after 15 months' treatment.

The Distribution of Iodine

Iodine existing on the earth in forms that are mostly highly soluble in water, the bulk of it is to be found in the sea whither it has been deposited by drainage water and when it exists in a concentration of less than 0.01 gm per liter. In the rocks which have had their origins in the sea, some traces of iodine remain and in the drainage waters flowing over and through them. This small trace diminishes in concentration as the tops of drainage areas are approached, there the soils being more thoroughly leached out. The same is true of thin strata of soils overlying impermeable rocks. In this connection attention is called to the remarkable results obtained by McClendon in his study of the iodine content of potable waters as related to goiter incidence.[26] Higher concentrations are found in soils and drainage waters occurring nearer the ocean, although here undoubtedly drainage is only one factor, as the supply of iodine is increased by sea spray blown inland.

Small and varying amounts of iodine may be found in plants and in the animals feeding upon them. The occurrence of iodine in food materials with relation to goiter has been studied by Forbes and Beegle.[27] While they find that there is not a sufficient divergence in iodine content of the foods grown in goitrous and non-goitrous regions to account for the varying incidence of that disease, they point out "the smallness of the proportion of our food products which contain iodine, the minute quantities in which iodine is ordinarily found and the haphazard nature of its distribution."

[26] "Simple goiter as a result of iodine deficiency," *J. A. M. A.*, *80*, 600 (1923).

[27] Bul. 299, Ohio Ag. Expt. Sta.

Just as the soils occurring near the ocean contain more iodine, so it is to be expected that the plants growing thereon will likewise, and it is shown by Hunter and Simpson, as stated by McCarrison, that the thyroids of sheep grazing near the ocean contain more iodine than those grazing inland.

But the occurrence of iodine to a remarkable degree in plants is confined to those that grow in the sea. In certain seaplants the iodine content, as will be shown, is phenomenal.

The foregoing suffices to show the intimate manner in which the normal supply of iodine for the metabolic use of the human body is linked with the sea. And in this connection it may be suggested that in this fact is found a biochemical bit of evidence in support of the theory of evolution, or at least that part which hypothesizes a marine origin of animal life. Our early metabolism being established on the basis of chemical elements always present in that medium of existence, it has not been possible yet to evolve a new system of life chemistry which can do without them. McClendon[28] voices the same idea in a different manner when he says:

> It has been considered by some biologists and chemists that living matter originated in the sea and the elements of living matter correspond to those found in the sea water. We might look, therefore, to the composition of sea water for the elements we should expect to find in living matter.

Entirely in support of this evident close relationship between goiter and the sea are the goiter maps here presented. The data on which they are based show that the incidence of simple goiter varies from 1.02 among men residing near the sea to 17.55 among those from inland regions. They illustrate the increasing incidence as tops of drainage areas, the Appalachians, the Great Lakes Regions and the Rocky Mountain Regions, particularly the Pacific Northwest, are approached. When multiplied by six they may serve to show the order of incidence among women.

It will be noted, by a comparison of the respective maps for "simple" and exophthalmic goiter, that there is a remarkable parallelism between the proportional incidences of the two forms. Both are derangements of the thyroid gland and both involve a deficiency of iodine in the gland. They occur side by side, the general conditions that induce one—so far as those conditions are understood—inducing the other. Both are the result of hyperactivity. In one the hyperactivity takes the form of hyperplasia, while in the other, of excessive secretion. Both respond to iodine treatment. Are they not obviously different manifestations of the same thing? One is demonstrably the result of iodine deficiency. There is no conclusion but that the other is also.

[28] "Are iodides food?" *Science, 55,* 1423 (April 7, 1922).

Lack of Iodine in Normal Diet

The modern diet is made up largely of highly refined materials, seeds constituting most of it. These, in their natural state, in addition to materials of great value as sources of energy, contain many of the mineral elements and compounds essential to animal life and growth. But in most cases they are refined to the point where the latter are eliminated. As a result when used alone they are not able to sustain life; it has been shown that animals fed on certain of them exclusively perish more quickly than do those entirely without food. The excessive use of refined foods leads to deficiency diseases. Over-refinement in food manufacture deprives us of essential elements which under less artificial conditions would be a natural part of our diet. No automatic method is provided for supplying these materials, of great importance in every case, but of the greatest importance in feeding the young. The diseases of the bones in growing children as a result of deficiencies are well recognized. Less attention is paid to the frailty and inadequacy of the teeth as a result probably of similar causes.

Together with deficiencies of the many commoner elements, there occurs, of course, an even more marked deficiency of iodine. The slight occurrence of iodine in food materials is shown by the elaborate research of Forbes and Beegle as illustrated by the following summary.

The various groups of food materials analyzed, in the order of the increasing frequency of iodine occurrence, are as follows: (1) Nuts; (2) spices, condiments and stimulants; (3) fruits; (4) cereals; (5) hogs, silage and forage crops; (6) garden vegetables and root crops; (7) leguminous seeds; (8) animal products, and (9) manufactured foods and milling and manufacturing by-products. "Among the cereals iodine was found as an uncommon constituent, usually in traces only."

Method of Supplying Iodine to the Diet

As a source of iodine for human metabolism it is obvious one must look to the sea, the great storehouse of that essential element, and choose that method of securing the requisite quantity in the manner which most readily coincides with one's already established dietary habits. Sea foods might well become a more common article of diet, but at the present cost for preservation and transportation do not reach the majority of people. Sea salt is not a commodity at present cheaply obtainable; its wide introduction as a condiment would be of great benefit to the human race. A logical and from many points of view an ideal conveyor of all these essential elements are the kelps, the larger sea weeds of the brown algae group.

Composition of Kelp

Chemical literature is replete with references to investigations of the composition of kelp. They have been studied from the point of view of their utilization as foods, and as carriers of inorganic salts and iodine.[29] The different species vary in chemical composition, quantitatively rather than qualitatively. Most of the work in America has been devoted to the giant kelp of the Pacific, *Macrocystis pyrifera,* made the basis of the extensive investigations of the U. S. Department of Agriculture. Its composition is more thoroughly understood perhaps than that of any other sea plant.

The composition of this kelp has been studied to determine its water, organic, inorganic, nitrogen, protein, sugar and fat content. It is tremendously complex, being made up of a great variety of organic and inorganic compounds and of organic compounds containing and combined with mineral elements. In organic combination are parts at least of the iodine, the phosphorus and the sulfur. In the plant, all of them are held in varying degree in colloidal suspension.

The many analyses of *Macrocystis pyrifera,* made in state and federal laboratories, show on the average: Potassium chloride 22 per cent., sodium chloride 10 per cent. and water-insoluble ingredients 7 per cent. (on the dry basis). Entering into this total of 37 per cent. inorganic material are: Calcium, 4.96 per cent.; magnesium, 2.24 per cent.; sodium, 10.52 per cent.; potassium, 29.46 per cent.; iron and aluminum oxides, 0.43 per cent.; chlorine, 34.93 per cent.; sulfur (calculated to SO_3), 7.92 per cent.; CO_3, 4.44 per cent.; phosphorus (calculated to PO_4), 2.30 per cent.

While all the kelps contain iodine, the iodine content of this species is phenomenal. Of 29 samples analyzed for that element, an average content of 0.26 per cent. was shown, with a maximum of 0.41 per cent. and a minimum of 0.17 per cent.

From the foregoing it is evident that this kelp contains the principal ingredients of sea water, and has stored them up within itself in even greater concentration than most of them exist in sea water. This is particularly true of potassium and iodine. It appears, therefore, to be an ideal concentration of the desirable elements of sea water with the relatively marked elimination of the most common and least valuable—common salt.

Adaptability of Kelp as a Diet Amendment

As a conveyor to the diet of the essential mineral elements, kelp possesses many ideal characteristics. It is a carrier of iodine of remarkable properties—a high content of iodine together with a great assortment of other useful elements. The source of raw material

[29] Turrentine, "Potash from kelp" (I–VIII), *J. Ind. and Eng. Chem.,* Vol. *11,* (1919), to Vol. *15* (1924).

is abundant. Methods have now been perfected whereby it may be so processed that its colloidal constituents remain unimpaired and its mineral content unreduced. When so processed it is a carrier of these elements and compounds in a natural, vegetable colloidal suspension, from which or through which they may be taken up by slow, digestive processes just as they would be if they were made available as natural constituents of usual articles of diet. Being highly concentrated in these, preparations may be made in condensed forms so that the convenience wherewith they may be added to the diet is greatly enhanced. For the latter purpose they may take a variety of forms, suitable for addition to the diets of people of varying ages and dietary habits. It is important that kelp to be used for the control of goiter be employed as a preventive as well as a cure, particularly that it be added to the diet of the young and to all those approaching or experiencing life crises. It is contended by some that its addition to the diet should be made a part of a culinary or dietary routine and not left to chance or the caprices of the memory. On the other hand, the disciplinary and educative advantage to be had from consciously taking as a diet amendment a concentrate of essential elements must not be overlooked. Being abundant, cheap and conveniently acquired, transported and stored, it should be made available for all peoples of all lands. Through its instrumentality, as a carrier of iodine and other desirable elements, not only goiter but other diseases depending on related deficiencies may be eradicated.

The present methods of combating goiter by the administration of metallic iodides or thyroxin leave much to be desired. The administering of iodides, as, for example, dissolved in the drinking water of a school, results in uneven dosage, though rarely in such an excess dosage as to cause symptoms of iodine poisoning; yet Bircher[30] describes the practice as causing harm and is supported by others in this contention.

What the situation requires is iodine in a form as closely as possible approximating the natural form in which that element is normally taken into the body, in organic combination, preferably as a constituent of food materials. Salts of iodine radically fail to meet this requirement. Those employed are very soluble and therefore are able to overcome the natural metabolic balance of the body solutions and thus rapidly to force their way into the circulation and out. The situation calls for a food, not a drug.

With a natural food material at hand, the wisdom of resorting to drugs for feeding is open to question. It must be remembered that iodine is administered in goiter not on account of any physiological action it may have as such. On the contrary, its physiolog-

[30] Schweiz, Med. Waschr., *52*, 713 (22).

ical action—as exhibited by iodism, for example—is exactly what one desires to avoid. It is given merely to furnish raw material to the thyroid wherewith to manufacture essential secretions. The situation demands physiologically inactive iodine, insofar as such is attainable.

Soluble iodine is not necessarily assimilable iodine. And in this connection it may be remarked that while the interconnection between iodine and goiter has been known for a hundred years no appreciable impression on the progress of the disease has been accomplished by the use of iodides. On the contrary, it appears that goiter is on the increase, a fact attributable to the increased use of refined foods and of surface water for drinking purposes and demands for nervous energy occasioned by our modern social régime.

Curative Powers of Kelp

This suggested use of kelp, based on *a priori* considerations, has within recent months been subjected to a rigid clinical demonstration with results so uniformly favorable as to exceed expectation. Under the supervision of skilled endocrinologists victims of goiter of a variety of involvements have been treated with standardized kelp extracts and with very few, if any, exceptions have responded favorably. Under this treatment heart action and metabolism have been restored to normal, the swelling of the thyroid glands reduced, nervous disorders have disappeared and in every case where frequent periods of violent insanity formerly occurred—requiring the confinement of the patient in an institution—these have entirely ceased to appear.

The Eradication of Goiter

The importance of maintaining the proper functional activity of a gland as vital to our physical well-being as is the thyroid can not be overestimated. The ease with which that may be done makes its neglect inexcusable.

The time has now arrived when goiter must be eradicated. Our knowledge of the cause of the disease, its prevention and cure has reached the stage where we can proceed with confidence to that end. Those responsible to the public for the state of the public health, those interested in the betterment of public health are now in a position where, with cooperation, through moderate educational propaganda, they can persuade the public to take for itself the simple step which will insure an adequate iodine supply in the diet to prevent the development of goiter, to arrest the course of the disease where developed, and in the majority of cases to effect cures. By concerted action within a brief period this dread disease may be eradicated—and further honors thus be made to accrue to those who are devoting their lives to disease eradication through preventive medicine.

SOME COMMON BUT LITTLE KNOWN CAVE DWELLERS

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In the dark recesses of a cavern like the Mammoth Cave of Kentucky there may be found thin-skinned, white, blind creatures of different kinds, and we call these cave animals.

All surface soil has somewhat similar but infinitely smaller crevices and crannies distributed through it. In these spaces are found innumerable animals. Some of these are surface animals which use the crevices for permanent homes or merely for temporary hiding places. Such animals are in the soil only incidentally. The squirrels which live in holes in trees in the eastern United States are represented in California by burrowing forms. These "ground" squirrels, however, obtain their food from the surface as the eastern squirrels do and use burrows as the most easily obtainable homes.

The prevention of evaporation from the surface of the body is one of the important problems for land animals. A thick, impervious covering of armor plate such as covers lizards, insects or pill bugs, or an oily, flexible, hair-covered skin like the mammals have is an effective moisture conserver.

Animals of this sort, though they may live underground, are pigmented normally and spend much time on the surface in the light. Most species of ants are examples.

There are, however, a number of animals, white and blind, which live permanently in the semi-microscopic chambers in the soil and are visible only by accident. Among these forms are included a few of the smaller worms, a number of the more delicate wingless insects, tassel tails and spring tails, and two of the orders of that artificial group of animals, the Myriapods.

These are all small animals, able to make their way between the superposed leaves on the forest floor or the particles of soil in it and find their food in such constricted spaces. They never of their own choice come to the light nor are they found where the atmosphere is far from the saturation point. In the soil they live and breed, migrating upward or downward as the combination of heat, light, food and water supply determines the optimum living conditions.

In order to show the relationship of the Myriapods to be discussed it will be desirable to give a brief history of the class.

In the twelfth edition of the "Systemae Naturae" in 1766, Linnaeus included the Myriapods with insects and named a number of species of both centipedes and millepedes. Since classifying had not yet arrived at a settled system the writers who followed Linnaeus shifted the Myriapods according to their pleasure, classing them with spiders, with scorpions and even with serpents. Early in the nineteenth century Leach took the name proposed by Latreille and constituted as a separate class the Myriapoda or thousand legs.

In 1887–88 Pocock and Kingsley, studying the Myriapods from the standpoint of relationship, each came independently to the conclusion that the group was not a natural one, because the possession of a larger number of legs than three or four pairs was not a sufficient basis for grouping. They recommended that the Myriapods should be split into two unequal groups, the one to contain the diplopods or millepedes, the symphyla and the pauropods and the other to include the chilopods or centipedes. This latter group is quite closely related to the insects, many of which have more than three pairs of legs either as embryos or adults.

This is the accepted classification to-day, though we may and probably will retain the name Myriapoda as a convenient if unscientific name for four very different types of jointed-legged animals.

The arguments for this separation of the Myriapods into two sections are numerous and convincing.

The most fundamental is that in the millepedes, symphylans and pauropods the reproductive organs open on the ventral side of one of the anterior body segments (2–4), whereas the centipedes, as the insects, have the sex opening at the posterior end of the body.

The centipedes all possess anterior legs transmuted into poison fangs, while the millepedes have no such organs. Many millepedes are provided with repugnatorial glands along the sides of the body which secrete an unpleasant protective material like hydrocyanic acid.

In general the centipedes are carnivorous and the millepedes herbivorous.

The Symphyla and Pauropoda are the least known of the myriapod orders because of their small size and their light-shy habit of life. They are, however, not uncommon where the conditions of heat and moisture are satisfactory, and the Symphyla especially have been long known.

In 1763, Scopoli saw and described one of these small animals, naming it as of the centipede genus Scolopendra and its species nivea or white.

In 1836 Gervais discovered a similar creature which he took for a larval Geophilid and called Geophilus junior. But on counting the antennal joints he found that it had more than any adult Geophilid possesses, so he named the animal Scolopendrella, the diminutive of Scolopendra, the centipede.

Because of its habitat in the soil he maintained the genus among the Geophilidae. Newport, the English myriapodist, however, removed Scolopendrella from the Geophilidae and placed it as the Scolopendrellidae, a family of equal rank, between the two carnivorous forms of centipedes, the Lithobüdae and the Scolopendridae.

To quote from Latzel, "these harmless things must have been not a little worried at being set down between such outspoken robbers and it was high time a savior should appear for them. This savior has lately appeared in the person of the American naturalist, J. A. Ryder, who has taken the poor creatures out of their unnatural environment and has made them the type of a separate Arthropod order, the Symphyla or connecting link."

Ryder's idea was that since Scolopendrella presents so many characters which also appear in the lowest insects, it must represent a connecting form between insects and myriapods. Time, however, has not dealt gently with this conception, and the Symphyla, instead of being considered the simplest myriapods and closely related to the primitive insects, now appear to be among the most specialized of their race and a terminal branch of their particular line.

The Pauropods

The Pauropoda were so named by Lubbock in 1866 because they have but nine pairs of legs, the least number found in any adult myriapod. The first species was dedicated to Professor Huxley. There are now three genera and a number of species known.

The order falls into two parts, the slow moving and the agile pauropods. By analogy with millepedes and centipedes, the slow moving pauropods should be herbivorous and the rapid ones carnivorous.

They range from one half mm to one and one half mm in length, the largest then being somewhere near one eighteenth of an inch long.

The pauropods have antennae which end in three flagellae. They are very different from the antennae of any of the other higher arthropods and suggest the branched antennae found in crustacea. These peculiar antennae make identification of the order very easy since in order to serve as eyes, ears and possibly nose for the animal they project notably from the sides of the head and from beneath the protecting armor when there is any.

The agile Pauropus is an ideal cranny and crevice dweller. Its body is much compressed from side to side and is set up high on the legs. The hinder legs are longer than the more anterior legs and it runs rapidly. It is able to make its way into the cracks in drying wood or similar spaces.

The slow moving Eurypauropus has a body compressed dorso-ventrally, covered with chitinous scale like armor, sculptured and variously ornamented. In this case the legs extend out laterally but do not project beyond the armor and the animal is adapted for creeping under the loosened bark of dead trees.

These animals are exceptional in that their small size permits them to oxygenate their tissues without any specific respiratory system such as the tracheae of millepedes. It has been suggested that the animal's fat body may have a respiratory function. The delicacy of the chitinous envelope and the size of the animal is such that each body cell is able to carry on respiration for itself.

As an accompaniment to this there is no circulatory system at all, since the physiological processes go on in such a small space that the body cells can obtain the food dissolved by the wall of the digestive cavity.

The cells of Pauropus eliminate their waste products (in the reverse direction of the oxygen intake) through the outside of the body, but the heavier bodied Eurypauropus has two intestinal diverticula or Malpighian tubules, as the millepedes and insects have, for excretory organs.

The young leave the egg with three pairs of legs, as do the regular millepedes. This hexapod condition was at one time very much stressed as indicating close relationship with the six-legged insects, but whatever significance it has must be that of parallelism, since the differences between millepedes and insects given earlier are fundamental.

Because of the exceeding small size of these pauropods little has been learned of the life history. When this shall have been learned for the two lines they may turn out to be more closely related to the regular millepedes than is now supposed.

The Symphyla

The Symphyla range from a maximum of eight mm in length downward. They are, therefore, notably larger than the Pauropods, but are still very small compared to the most of the myriapods.

There appear to be about 15 segments after the head. They are eyeless, with wonderfully sensitive antennae which look like little strings of pearls and can be elongated or shortened at the need of the animal.

They run quite actively, standing high on their legs and thus give the impression of small white centipedes. They can move backwards as well as forward. In the ground they often, if not always, spin a delicate thread of web from the cerci at the hinder end of the body as they travel and so they can retrace their path if it is necessary by following the web. They will always spin such a thread if they are carefully lifted from the substratum and then given the opportunity to drop.

When disturbed, they are likely to feign death, lying quiet with the body in the shape of a crescent. If then the animal be treated roughly the antennae will move hastily for information and the animal will wake up and hurry away.

There are at present two genera known in the order. The number of legs and the shape of the tergite or dorsal shield of the body segments determine to which of the two genera, Scolopendrella or Scutigerella, the individual belongs. Scutigerella as an adult has twelve pairs of legs with one pair of jointed appendages or parapods, near the origins of the last ten pairs. The tergites, of which there are 15 in number, have their posterior corners rounded and the last one is concave posteriorly. The tergites in Scolopendrella, on the other hand, have the posterior corners extended backward as sharp points and the hinder boundary of the last one is at right angles to the axis of the animal. Scolopendrella appears to have eleven pairs of legs, since the first pair of Scutigerella either does not appear at all or appears as rudimentary stumps.

The breeding season in Ohio comes in May and June. There is no evident difference between the sexes unless it be that the males are smaller than the ripe females.

In an enlargement in the runway the female deposits from three to eight eggs and bends herself about them, probably for the sake of keeping off fungous growth. The eggs are most beautiful objects, spheres, about a millimeter in diameter, pearly white with a geometrical pattern of ridges over the surface which reflect the light.

The American species fasten the eggs together in a ball with web, but a species reported from Malaysia spins a short stalk and sets the mass of eggs up on this stalk, thereby gaining a greater immunity from fungus or from the attacks of the semi-microscopical parasitic mites which rather commonly infest the adults.

The time of hatching is dependent upon the temperature. In one case where the eggs were laid in a space under a glass slide and kept under daily observation the time was ten days.

The larvae escape from the egg with either six pairs of legs (Scolopendrella) or seven pairs (Scutigerella) and add the rest of the legs in a series of moults.

The symphyla are reported to breathe by means of a pair of spiracles with attached tracheae which open on the head of the animal. If this is correct it is the only case known in the arthropod phylum. Without any doubt there is a series of eversible sacs found along the ventral side of the animal near the bases of the legs. Similar structures are found in Thysanura among the insects. It is suggested that these are respiratory organs. The method of oxygenation of the tissues through the delicate chitinous surface is probably the principal one.

There is a heart present, similar to the circulatory organ in larger animals of the arthropod type.

Excretion is carried on by means of Malpighian tubules.

The alimentary canal is essentially a straight tube. The question of what they eat is not definitely settled. The agility and rapidity of movement and the fact that the mouth parts grasp forward, as in the centipedes, instead of downward, as in the millepedes, together with the simplicity of the alimentary system, would indicate a carnivorous habit. There are numerous microscopic protozoa and arthropods in humus such as the symphylans frequent. The fragments of wood which are found in sections of the digestive cavity could be taken accidentally along with the animal food or of course might be the less digestible part of a vegetable diet.

General Considerations

Neither the pauropods nor the symphylans can survive steady trampling or cultivation of the soil they inhabit. They are therefore more likely to be found in undisturbed forests or the parts of pastures too rough to be tramped down by animals, or along the bottoms and sides of gullies where the stones are large enough not to be moved by common freshets.

When the leaves fall in the autumn, the ground is moist and the relative humidity of the air approaches 100 per cent., then both pauropods and symphylans may be found above the surface of the ground in the narrow spaces between the packed fallen leaves.

As long as decaying wood is moist it is also a favorable habitat, as it furnishes crevices small enough to protect from marauding animals. I have found Scutigerella breeding in wood in preference to soil, while Scolopendrella seems to prefer the soil.

When everything is dry in the late summer these animals go down in the soil or under heavy stones until they reach the favorable conditions of moisture and coolness.

Even in favorable situations they are likely to be found scattered in discontinuous groups rather than distributed uniformly throughout the soil. The type of habitat, the crevices in humus, can not

have changed much in the history of the world, and after these minute creatures were adapted to this habitat one would not expect them to change much either.

The two groups offer the same evidence for geographical distribution. Both pauropods and symphylans are found in both Europe and North America, the same genera and in some cases the same species. This fact demands a continuous land connection between Europe and America at a time after the differentiation of these two orders from the ancestral progoneate millepede-like stock.

In North America all life was destroyed during the glacial period as far south as the icecap reached. The organisms have migrated back again over the area left by the withdrawal of the glaciers.

The islands of Lake Erie have been separated from the mainland ever since the disappearance of the ice by the waters of the lake now called Lake Erie, which in the past was a much larger body of water than at present.

Wingless animals which can not swim have had to be taken to the islands by some transporting agency. Creatures like the pauropoda and symphyla, which are so small that it is not likely that any larger animal would carry them, either by intent or accident, would have to depend for their dispersion on floating wood. This is probably the means by which all the millepedes, spiders and such forms reached the islands, since they are very likely to conceal themselves in the crevices of decaying wood.

Scutigera, the house centipede, does not live in wood but in the crevices between stones. Although there are favorable stone habitats on most of the islands and although Scutigera has been found on Marblehead peninsula only a few miles away, it has not been found on the islands. We may conclude, then, that all myriapods found on the islands of Lake Erie have reached there by the driftwood route within the last ten thousand years or whatever time it has been since the last withdrawal of the ice from Ohio.

The Symphyla and Pauropoda will never be of any significance to the average man because of their small size, their limited numbers and their lack of economic importance. They are wonderfully well adapted to the underground environment, however, and will probably persist as long as there are favorable undisurbed situations where they can find their minutes caves in which to dwell.

BOTANIZING IN PERU

By Dr. A. S. HITCHCOCK
U. S. DEPARTMENT OF AGRICULTURE

On October 11 I left Guayaquil for Callao the port of Lima. The prospective traveler to Ecuador should know that it costs something to get out of that country as well as to get in. I was obliged to get a permit to leave, costing sucres 20.80, before the steamship company would sell me a ticket.

As the steamer stopped for a few hours at Paita, I landed to look things over. Although only a short distance from the southern border of Ecuador the country was a desert. No living thing could be seen on the hills around the town. This was the beginning of the great desert extending from northern Peru into northern Chile. Throughout this region the population is found in the isolated valleys of streams that flow from the Andes to the ocean, their waters providing irrigation for agricultural industry of the coastal plain. The most important crops are sugar and cotton. The isolated communities of these valleys depend upon steamer service for their communication with the outside world as there is no railroad paralleling the coast.

The sea was calm, as it usually is along the Pacific coast of South America, the sky was bright and the weather cool, so cool in fact that I had to wear a sweater. At Salaverry I saw a wonderful sight. The steamer was anchored off shore and just outside was a constant stream of birds flying northward, hour after hour, countless thousands, within a few feet of the surface, as far as the eye could reach in either direction.

As the steamer did not come to a dock at Callao there was the usual confusion in getting ashore by launch. Fortunately there is a tariff for charges. There is a blanket charge from the steamer to the hotel at Lima. This includes launch to Custom House, through the Custom House to train for Lima (about a half hour inland), and from train to hotel (2 trunks at 5 soles each, and 4 bags at 2.50 soles each, 1 sol for myself and hand baggage). The Custom House officials were very courteous, passing my baggage without opening it. After getting letters for use in the interior I started for Oroya and Cerro de Pasco, lying in the sierra over the western range of the Cordillera. The railroad is a wonderful piece of engineering. We first traverse the coastal plain and begin to climb about 10 o'clock. Then we do some of the most spectacular

climbing I have ever seen. At 3 o'clock in the afternoon we go through a tunnel (3,757 feet long) at the summit of the pass at an elevation of almost 16,000 feet. There is a severe strain on the human organism in going to such an altitude in so short a time and many suffer from soroche or mountain sickness. It was fortunate that I was not affected by altitude as I was in the sierra for about ten weeks. The construction difficulties may be estimated from the fact that on the road including the branch to Huancayo there are 65 tunnels, 10 of them more than 500 feet, 21 switchbacks, and 61 bridges.

At Oroya (12,000 feet) is the big smelter for the Cerro de Pasco copper mines. Fortunately I had the privilege of stopping at the company's hotel which was very comfortable. The rooms were heated with electric stoves and the meals were American style. Mr. Colley, the manager of the smelter, kindly made arrangements for a trip to Colonia Perené, a plantation in a valley to the east. An autobus took me over a high páramo or puna to Tarma, and another down a long slope of about 10,000 feet to La Merced. The road on this slope was good but so narrow that autos cannot pass and the traffic goes up one day and down the next. The descent was made in the rain, after dark, at a terrific speed, a precipice on one side and a drop-off on the other, around sharp curves, the driver half Chinese and half Indian—altogether a hair-raising ride. My anxiety was increased by watching the speedometer as it hovered between 30 and 35 miles an hour. On the return trip I discovered that the speedometer recorded kilometers instead of miles (1 km. = 0.6 miles). The following day I went mule-back to Colonia Perené where my letter brought a warm welcome from the manager, Sr. Valle-Riestre. The plantation is devoted mostly to coffee of which there are 1,600,000 trees. As the altitude is 2,000 feet the flora was tropical.

The next stop was at the Atocsaico Ranch about 12 miles west of Junín. This ranch is chiefly devoted to sheep. During the ride from the station to the ranch we passed through a hard sleet storm. At the ranch I was looked after most hospitably by the manager, Mr. McKenzie (and his assistants McLeod and McLean—none of them Frenchmen), and Sr. Rizo-Patron, son of the owner of the ranch. My! How I did enjoy the oatmeal and cream—real cream, something I had not seen since I left the states. Here, at 13,000 feet the grazing is excellent all the year, plenty of grass, plenty of water, ideal for sheep. At this altitude there are no trees and fuel is expensive. At the little stove in the ranch house dried turf was burned. Sheep manure is also used. There is a dynamo and soon the power, light and heat at the ranch will be electrically

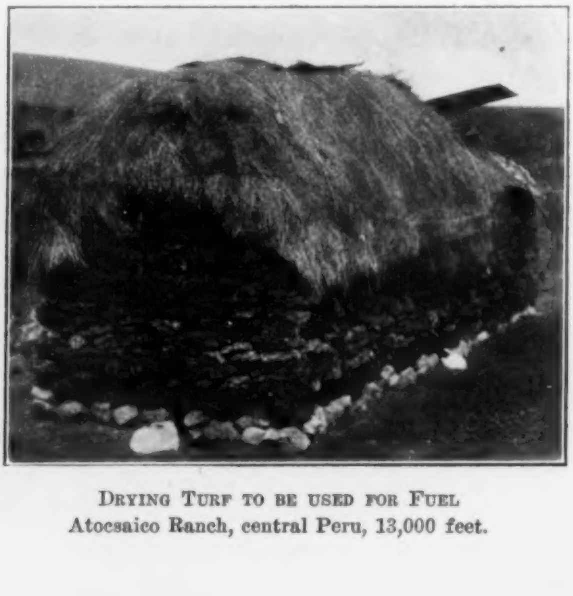
Plaza at Arequipa
Mt. Misti (19,200 feet) in background.

supplied by water power. Those who have not visited these high altitudes can scarcely appreciate that even in the tropics the climate is cold and bleak. Although well prepared I was constantly fighting the cold. I had a good bed at the ranch but there was no heat.

Stone Hut, Atocsaico Ranch, 13,000 feet

Cactus near Arequipa
Sr. Delgado Vivanco in center.

There were eight blankets on the bed and Mr. McKenzie had thoughtfully provided a hot water bottle for my feet. With all this I was cold and finally got up and put on wool underwear, still later I put on a wool shirt—only then was I warm. Sitting during



Drying Turf to be used for Fuel
Atocsaico Ranch, central Peru, 13,000 feet.

the evening in a chilly room increases the sensitiveness to the cold after retiring. On the ranch (11,000 acres) there are about 35,000 sheep and the annual production of wool is about 60 tons. In one of the barns was an immense pile of condor wings upon which a bonus had been paid. Condors are a great pest here as they destroy the sheep.

After three pleasant days at the Atocsaico Ranch I went on to Cerro de Pasco, the seat of the great copper mine, where I had the privilege of stopping at the company hotel. Cerro de Pasco is a cold bleak place at 14,300 feet altitude and I appreciated the steam heat at the hotel. The railroad from Oroya to Cerro de Pasco passes

WOOLLY CACTUS (*Opuntia floccosa*)
Atocsaico Ranch, 13,000 feet. Fountain pen in center.

over a great high plain 13,000 to 14,000 feet elevation, with mountain ranges still higher in the distance.

The hills around here are covered with a curious tussock grass called moss-grass (*Aciachne pulvinata*) of no use for forage. The bunches are hard, with a covering of short spiny leaves. As the bunches increase in size they die in the center, thus forming fairy rings.

Mr. Philpott, the manager of the mines, interested himself in my work and made arrangements for a trip to La Quinhua, a gold mine, down one of the valleys, and to the company's coal mine at Goyllarisquisca (it took me a long time to understand this word). I remember the trip to La Quinhua because I got so cold coming

TERRACED FIELDS, AREQUIPA
Crops are grown under irrigation in all the valley and well up on many of the slopes.

back. I had on heavy cotton underwear, an army wool shirt, a heavy wool sleeveless sweater, a vest, a wool-lined leather vest, a coat, a heavy waterproof poncho, seven thicknesses, yet on my arrival at the hotel that night in a cold rain I was suffering greatly from the cold—and it was in the tropics, 11° south latitude.

At Goyllarisquisca, I went with Mr. Tweedie, the manager, to the coal mine down a steep valley 5,000 feet by a cable car. Here was excellent collecting. In telling Mr. Philpott about it afterwards, he remarked, "In other words, you made a killing."

Although I did not suffer from soroche I noticed the rarefied atmosphere, particularly when at rest. Under these conditions my

OLD SPANISH PITS USED FOR EXTRACTING SILVER ORE
Valley north of Cerro de Pasco. Heavy stone rollers crushed the ore.

lungs were accustomed to slowing down, and suddenly I was not getting air enough and involuntarily must take a deep breath. This was particularly troublesome when I was going to sleep at night. Just as I was falling into unconsciousness a gasp would arouse me to full wakefulness, accompanied by a feeling of anxiety. This might continue for half an hour before I finally fell asleep. I did not observe this effect at lower altitudes, not even at 13,500 feet.

Returning to Lima I took passage for Mollendo, the terminus of the Southern Peruvian Railroad, by which I could reach Cuzco and La Paz. I was fortunate in finding the hills green around Mollendo and therefore remained here two days to collect. This, like the rest of the Peruvian coast, is a desert, but occasionally at this point there are showers which bring the hills to life for a short time. The verdure was found in a band only a few miles wide.

MOUNTAIN ROAD, TARMA TO LA MERCED
Because of the narrowness traffic went up one day and down the next.
Montaña on eastern slope of Cordillera.

On the way to Arequipa the train passes the curious crescent-shaped sand dunes that at once attract attention. These are very regular in shape, white sand against a dull flat plain, all moving in one direction, that of the prevailing wind. The dunes appear to be 10 to 15 feet higher in the middle, and about 100 feet across, tapering evenly to the two horns of the crescent.

Arequipa (7,500 feet) is a very pleasant place in a rich agricultural valley. There are three high mountains in the vicinity, Chachani (20,000 feet), Misti (19,200 feet), a regular cone, and Pichu-pichu (17,800 feet). There is at Arequipa a good observatory, a branch of Harvard University, at which Dr. Bailey was director.

PUNA OR PÁRAMO AROUND CERRO DE PASCO, 14,000 TO 15,000 FEET
Moss grass in foreground (*Aciachne pulvinata*).

A HERD OF LLAMAS, CERRO DE PASCO.
They carry loads of about 75 pounds and travel 10 or 12 miles a day.

THE COMPANY HOTEL AT CERRO DE PASCO, 14,300 FEET

I had a letter of introduction to Mr. Delgado Vivanco, from his brother, who was a classmate of my son's at the University of Maryland. Mr. Delgado arranged to take me on a day's ride into the country and was to call for me the following morning at 8 o'clock. He arrived promptly on time—American style as he explained to excuse his promptness.

My next stop was at the new Experiment Station at Chuquibambilla, on the high plain north of Juliaca. The railroad branches at the latter place, one part going to Cuzco and the other to Lake Titicaca and on to La Paz. Colonel Stordy, the director, was my host. The farm or ranch has about 18,000 acres with about 15,000

Moss Grass (*Aciachne pulvinata*)
at Cerro de Pasco, 14,000 to 15,000 feet, a pen knife in a tussock to indicate size. Note the tendency to form fairy rings.

sheep. The altitude is about 12,500 feet and the conditions are similar to those at the Atocsaico Ranch. There is a high plain from Lake Titicaca to La Raya, 12,500 to 14,000 feet altitude, about 100 miles long. It was difficult to realize that we were riding over a plateau nearly as high as Pike's Peak. The station is provided with modern equipment and is well stocked. The Peruvian government is to be congratulated upon the successful operation of this station. I had the unusual experience of playing tennis here and later at La Paz at altitudes between 12,500 and 13,000 feet.

After three days pleasant stay here I went on to Cuzco, going over the pass at La Raya and down into the next valley, the city

THE PUNA OR PLATEAU AT CHUQUIBAMBILLA EXPERIMENT STATION, 13,000 FEET
Ichu grass in foreground (*Stipa ichu*)

SHEEP AND YOUNG LAMBS ON RANGE AT CHUQUIBAMBILLA, 13,000 FEET
Excellent grazing throughout the year.

HOTEL AT OLLANTAYTAMBO, NORTH OF CUZCO
Llamas at rest in the plaza.

being about 11,000 feet altitude. La Raya is on the watershed that divides the rivers flowing south into Lake Titicaca from those flowing north into the Amazon. As one descends toward Cuzco there come to view cultivated crops at about 13,000 feet, barley and beans (called here habas, the European broad bean), and a

CLIFFS NEAR OLLANTAYTAMBO
with cactuses and other xerophytes.

little lower potatoes, alfalfa, wheat and corn (first at 11,600 feet).

The visitor in Cuzco, even a botanist, steps aside long enough to examine the Inca ruins. All over the city one sees the foundation walls of buildings destroyed by the Spaniards. At a glance the large-stoned Inca walls can be distinguished from the modern walls above them. On the hills outside the city are the ruins of a large fortress of which I took several pictures. Some of the stones are of immense size—one is said to weigh 361 tons. There are

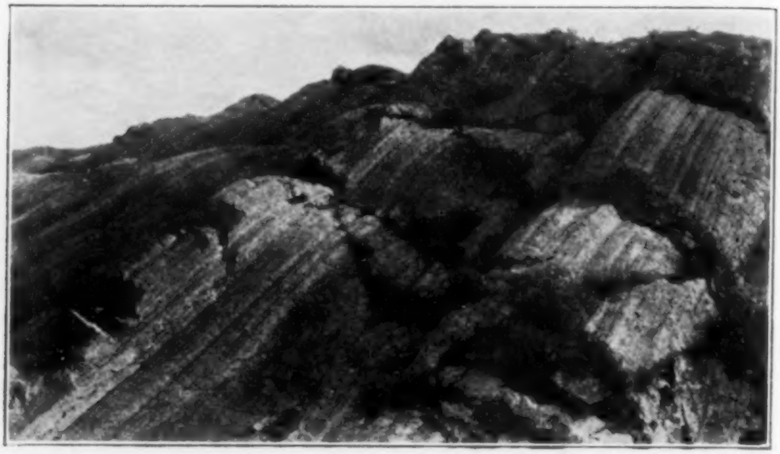
A Columnar Cactus supporting Numerous Tillandsias
Ollantaytambo.

several stones measuring 15 by 12 by 10 feet, and one 27 by 14 by 12 feet (according to a work describing the ruins). The most striking feature of the walls is the accuracy of the workmanship. The stones are fitted together with curves and angles, so perfectly that a knife blade can not be thrust between, and yet no cementing material was used.

There is a new railroad under construction from Cuzco down the valley north to Santa Ana. Trains now run nearly to Ollantaytambo. I was fortunate in getting in touch with the officials. Through the courtesy of Sr. Almenara Butler, Sr. Romero Sotomayor, the engineer, and Sr. La Torre, I was able to go to Ollantay-

STONE WALL, CUZCO, COVERED WITH CACTUS TO KEEP OUT INTRUDERS
Eucalyptus Grove.

A PART OF THE RUINS OF THE INCA FORTRESS AT CUZCO
The larger stones weigh many tons.



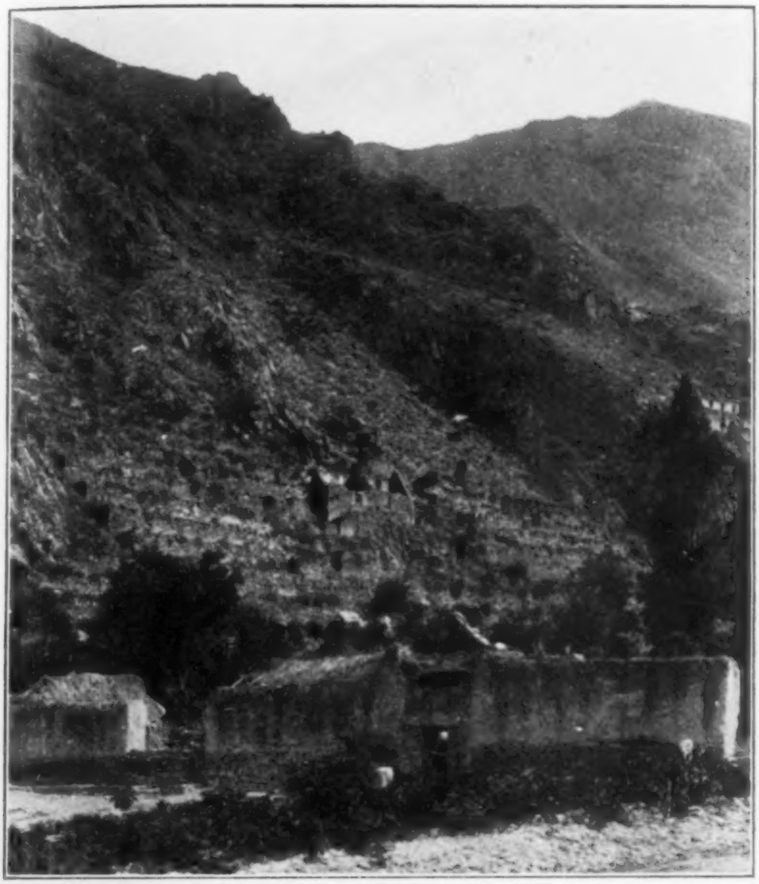
A STONY HILL BETWEEN THE FORTRESS AND THE QUARRY FROM WHICH THE STONE CAME

It would appear from the striated ridges that the stones were drawn over this hill.

tambo. In company with Sr. La Torre, who was paymaster, I went by horse, about 15 kilometers further, he, with his saddlebags full of silver, paying the workmen who were grading for the road.

A NEAR VIEW OF A PORTION OF ONE OF THE WALLS OF THE FORTRESS AT CUZCO

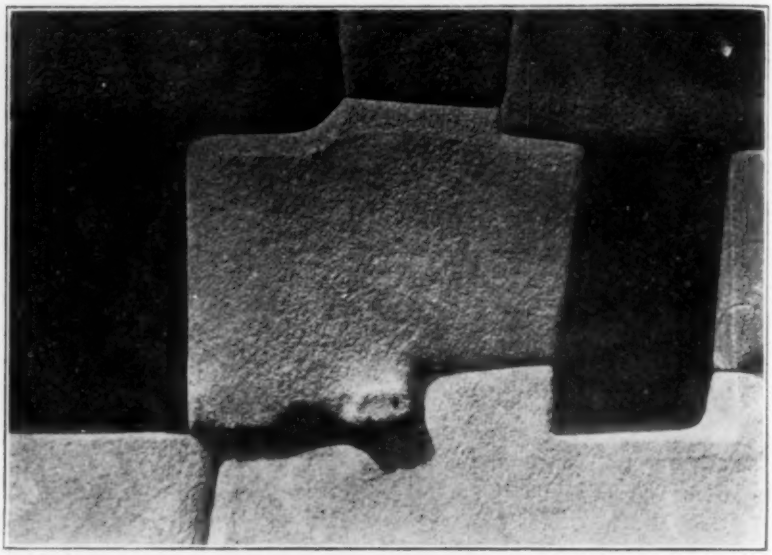
The stones are fitted very accurately and without cement.
A drainage hole is shown.



OLD INCA TERRACES AT OLLANTAYTAMBO
The cultivated fields, now abandoned, were carried up the slopes on these terraces and irrigated.

On the train a talkative gentleman told me many things about the places I would visit. My knowledge of Spanish is not excessive and there were two key words that I did not recognize. So I looked these up in a pocket dictionary. Ah! pulga and piojo, flea and louse! There were many of these where I was going and I must be careful.

While climbing over the rocky cliffs at Ollantaytambo I stumbled and, putting out my hand quickly to save myself, thrust it into a clump of cactus (Opuntia) with barbed spines. I removed all the spines I could but many were broken off below the surface and these gradually worked out during the next two weeks. But at one place



A Close View of a Stone in a Wall of the Ruins at Ollantaytambo
Showing the exactness of the fitting. No cement was used.

Immense Stones on the Top of a Hill at Ollantaytambo
Part of Inca ruins similar to those at Cuzco.

AN OLD INCA ROAD, OLLANTAYTAMBO

The stones were transported over this road from the quarry many miles away. This stone was abandoned. The Incas had no beasts of burden and no iron.

my finger became badly infected and I was obliged to perform an operation on myself. I always carry with me a pocket dissecting case and a few simple medicines including iodine. I cleansed the surface and the scalpel with iodine, cut deeply and applied iodine. Fortunately the infection was destroyed and the wound healed. One of the anxieties of the traveler here is to keep well, for outside of the cities there are no physicians.

There are more Inca ruins around Ollantaytambo, similar to those around Cuzco. There are also many old terraced fields on the steep hillsides, stone walls, one above the other, with a few feet of level soil between, stretching far up the slopes. The terraces were irrigated by the Incas but are now abandoned. Yet the present inhabitants terrace and irrigate extensively.

Returning to Cuzco I made preparations for my journey to La Paz.

THE PHYSICAL BASIS OF DISEASE

By THE RESEARCH WORKER
STANFORD UNIVERSITY

VI. ABNORMAL FUNCTIONAL ACTIVITY

"I HAVE but one more group of diseases to present," said the research worker, as the men returned from the observation car, "diseases due to abnormal activity of important organs of the human body not caused by demonstrable changes in the structure of these organs."

"You mean normal organs can produce disease?" said the manufacturer.

"I purposely used the words 'demonstrable changes in structure.' It is possible structural changes may exist not detected by present microscopic methods. Improvements in microscopic technic in the past have often led to the discovery of structural changes not suspected by earlier workers.

"Abnormal activity of an apparently normal organ may be caused by numerous factors. Among these are chemical overstimulation or chemical depression of the organ. Abnormal nervous impulses going to the organ may also cause unusual activity. The abnormal nervous impulses may of course be of purely psychical origin."

"Then you do admit disease may be of mental origin," said the lawyer. "I thought medical men looked upon such claims as pure bunkum."

"The activity of many organs of the human body may be sufficiently modified by purely psychical factors to cause disease. The conflict between biological science and 'spiritual healers' is not over this point. It is over the claim of these 'healers' that all diseases are the results of abnormal psychical or 'spiritual' forces. Particularly their claim that all diseases can be cured by altering these forces. They are apparently ignorant of the well-known structural changes in the majority of human diseases."

"Christian Scientists claim they have revelations in advance of medical science," said the lawyer.

"The beliefs of Christian Scientists, so far as they relate to the cause and cure of human disease, are not new revelations in advance of biological science. They are really curious survivals of primitive conceptions, discarded by biologists centuries ago. All

primitive people look upon disease as the result of abnormal 'spiritual' forces. Treatment consists in attempts to expel invading demons, or propitiate angry deities. Christian Scientists have merely reworded these primitive conceptions in terms of orthodox Protestant Christianity."

2

"Probably the simplest example of abnormal activity of apparently normal organs is abnormality in the action of the sweat glands. The sweat glands, as you know, have a definite rôle in the heat regulation of the body, requiring accurate adjustment between the temperature and the amount of perspiration. Abnormal chemical factors may cause an overactivity of these glands, with excessive perspiration on the body as a whole, or on certain skin areas. Abnormal neurotic factors may produce the same effects. This is a familiar phenomenon in fear and certain other emotional states. Highly neurotic individuals often suffer from constant or intermittent dampness of the body as a whole, or of certain skin areas. Or, they may have the opposite phenomenon, constant or intermittent dryness of the skin.

"More important are the abnormalities in skin circulation. The amount of blood flowing through the skin varies from time to time. This variation is brought about mainly by relaxing or constricting the skin blood vessels. Certain chemical substances injected into the skin will throw the blood vessels into such extreme state of constriction that local circulation practically ceases. Electrical stimulation of certain nerves may produce the same effect. In highly neurotic individuals it occasionally happens that neurotic narrowing of the skin blood vessels is sufficiently prolonged to cause marked changes in the nutrition of the skin, unpleasant tingling sensations, even pain. In extreme cases gangrene may result. This gangrene is one of the best illustrations of structural changes in the human body produced by abnormal nervous factors."

"Psychical gangrene," said the lawyer. "That must explain the miraculous 'wounds of Christ' in religious fanatics."

"Many modern cases of alleged miraculous appearance of wounds on the hands, feet and side during religious excitement or religious mania have been investigated. In practically all cases in which unbiased investigation was possible, the wounds were shown to be due to conscious or unconscious self-mutilation. The location of the wounds is not such that they could be readily produced by neurotic constriction of local blood vessels. Of course, medieval cases were not investigated.

"In place of a local narrowing of the blood vessels, a local dilation may take place, causing redness and swelling of the skin. You

probably know individuals who suffer from such blotches of redness and swelling after eating certain articles of food. These food idiosyncrasies are readily reproduced in animals. The idiosyncrasy is due to chemical abnormalities."

"'Chemical abnormalities!'" interrupted the lawyer. "Our Boston friend would say 'spiritual abnormalities.' Aren't both expressions synonymous with ignorance of the real cause of the idiosyncrasy?"

"If blood is drawn from an animal in which an idiosyncrasy to a certain food has been artificially produced, and this blood is injected into a normal animal, the normal animal will show the same idiosyncrasy. Distinct chemical differences can be shown to exist between the blood of this animal and normal blood. The idiosyncrasy is believed to be due to these chemical differences."

3

"Probably the most interesting psychical disturbance in external parts of the body is psychical, neurotic or hysterical disturbance of skin sensation. One of the commonest forms is a partial or complete loss of sensation in certain skin areas. A leg, for example, into which pins can be inserted without the knowledge of the individual."

"Don't see how such a thing is possible with a normal brain and normal skin," said the manufacturer.

"The loss of skin sensation is in some way connected with the psychology of consciousness. Most of our skin sensations normally fluctuate between the conscious and the unconscious, depending largely upon attention. One can easily conceive the hysterical loss of skin sensation to be due to an exaggeration of this normal fluctuation. Loss of sensation in certain skin areas is often likened to a condition of sleep in certain portions of the brain. This, of course, is merely a figure of speech. The underlying cause is unknown.

"The numb areas usually show marked variations in size, shape and location from day to day. The numbness may persist for months or it may suddenly disappear under emotional excitement. Similarly, psychical, neurotic or hysterical losses of sensation may take place in the special senses—psychical deafness, neurotic blindness, hysterical loss of smell. These disturbances also may disappear under emotional excitement."

"That must explain the alleged religious cures of blindness," said the manufacturer.

"The only authentic modern cures of blindness under mental therapy, religio-therapy and other forms of emotional appeal are

cures of psychical, neurotic or hysterical blindness. There is no case on record of blindness due to structural defects cured by these methods.

"Psychical, neurotic or hysterical factors may produce the opposite effect, exaggeration of the normal skin sensations. Probably the commonest form is the development of certain skin areas in which the slightest touch brings forth disagreeable sensations, even pain. In extreme cases, excruciating pain may be felt with no demonstrable external stimulus. Such areas of tenderness or pain are usually interpreted by the individual as indices of underlying organic disease."

"Is it known how these false sensations are produced?" asked the manufacturer.

"Too little is known of the psychology of consciousness to adequately explain these sensations. Normal skin sensations can be magnified in consciousness, even to the point of discomfort, by directing the attention to certain skin areas. Memories of former pain probably play a rôle. Twenty years ago I had a couple of teeth extracted for alveolar abscess. I have but to direct my attention to that side of my face to feel again the toothache of my early manhood. The dull local pain may be sufficiently strong to be a real discomfort. I am often conscious of this pain when overfatigued or emotionally upset.

"The areas of neurotic tenderness may vary in location from time to time. The tenderness may persist for months, or may disappear under emotional excitement. Similarly, heightened sensations, even false sensations of sight, hearing, taste and smell may be produced by neurotic factors, with no demonstrable structural changes to account for them."

4

"Probably the most dramatic functional disturbances in external parts of the body are psychical, neurotic or hysterical disturbances in the muscles. One of the commonest is an increased sense of muscle fatigue. In extreme cases, painful muscular weariness on exertion, incapacitating an individual for physical work."

"I've employed some of these guys," said the manufacturer. "Born tired. No sympathy with them."

"We all show this phenomenon to a minor degree—the sense of bodily weariness on disappointment, discouragement or after business reverses. If you knew the psychical factors causing the exaggerated fatigue sense in these 'guys', you might feel sympathy for them.

"Somewhat less common are the psychical, neurotic or hysterical paralyses. Loss of the use of an arm, a leg or of half of

the body. Hysterical paralysis is one of the common results of industrial accidents. It was very common with soldiers during the late war."

"I bet these soldiers were given a swift kick by the military authorities," said the lawyer.

"On the contrary, they received serious, even courteous treatment. In England, for example, a certain hospital was set aside for their care. It was found that hysterical paralysis, even of long duration, could usually be cured in a few hours by carefully explaining to the individual the nature of his paralysis, showing him the physiological tests by means of which structural defects were ruled out, and getting his intelligent cooperation in an intensive reeducation of his muscles. A soldier who had not walked for a year might be brought to the hospital on a stretcher in the morning and be out playing tennis in the afternoon. Slightly wabbly, of course, from motion pictures exhibited in this country by the British military authorities; but back at the front in a month's time."

"A logical field for Christian Science," said the lawyer.

"The alleged miraculous cures of paralysis under various forms of religio-therapy are all cures of psychical or hysterical paralysis. There is no case on record of paralysis due to structural defects cured by these methods. Religio-therapy might be a logical treatment for such cases, provided all physicians and all patients were sincerely convinced of the truth of the religious doctrines involved. So long as these doctrines are regarded with skepticism by an appreciable number of people, the method will not be generally applicable. Modern methods of intellectual appeal are equally efficacious.

"Other striking psychical, neurotic or hysterical disturbances of the muscles are the various uncontrollable twitchings, jerkings, tremors and complex muscular movements. These neurotic manifestations may also vary from time to time. They may disappear under emotional excitement. Most of us show minor forms of this phenomenon, being rather 'jerky' when over-fatigued, or after loss of sleep."

5

"Functional disturbances similar to those of the external parts of the body are common in internal organs. We shall only have time, before the dining car opens, to take up two or three examples.

"Probably the simplest example is abnormal activity of the bronchi in certain types of asthma. This type is easily reproduced in animals. Guinea-pigs, for example, readily develop an idiosyncrasy to certain foods. On injecting these food materials

into artificially hypersensitized guinea-pigs, violent asthmatic attacks occur, often sufficient to cause death within a few minutes. Autopsies show that this death is due to a sudden constriction or narrowing of the smaller bronchi, preventing the entrance of air into the lungs. The constriction is brought about by abnormal chemical reactions, stimulating the bronchi into prolonged spasmodic contractions.

"In the same way abnormal chemical reactions can produce disturbances in other organs of the body, sufficient to cause distressing symptoms, even death—gastro-intestinal symptoms, disturbances in circulation, altered urinary excretion, unconsciousness. Abnormal chemical phenomena of this nature constitute my own particular field of research.

"Equally striking disturbances of apparently normal internal organs may be produced by psychical, neurotic or hysterical factors. Probably the simplest illustration is psychical disturbances to digestion. The amount of each digestive fluid is normally adjusted to digestive needs, the adjustment being largely automatic, depending upon the volume and nature of the food. The amount of each digestive fluid, however, can be modified by psychical factors independent of digestive needs. The flow of saliva, for example, is greatly increased by thoughts of food. Salivary flow may be almost completely stopped by fear. I believe psychical suppression of saliva has been used in the detection of crime, the guilty individual being unable to eat dry foods such as crackers."

"The test doesn't work," said the lawyer, "except in highly impressionable individuals."

"Most of the neurotic disturbances we are considering occur in individuals of this type.

"Psychical factors may in the same way modify the secretion of the internal digestive fluids. A good illustration is the increased secretion of mucus in the digestive tract in certain neurotic conditions. A small amount of mucus is normally secreted as a lubricant to the intestinal canal. In certain neurotic conditions large amounts of mucus may be discharged with the intestinal contents, stringy masses, even tubular casts of the intestine resembling sloughed-off layers of intestinal lining. These mucus discharges are often interpreted by the individual as grave intestinal disease. The discharge may vary in amount from time to time or may completely cease under improved psychical conditions.

"Psychical factors often produce the opposite effect, decreased gastro-intestinal secretion. The gastric juice, for example, may be greatly reduced in amount. Or there may be a reduction in one or more of the important components of the gastric juice. One

of the principal components, as you know, is acid. This acid acts as a food preservative. A reduction in the amount of gastric juice or a reduction in the percentage of acid in the juice, tends to allow fermentation and putrefaction to take place in the stomach, with the formation of gases and other disagreeable products. This is my own favorite form of digestive upset after loss of sleep, disappointment or domestic friction.

"Psychical factors may produce equally striking digestive disturbances by modifying the motility of the digestive tract. The passage of food is brought about, as you know, by orderly automatic expansions and contractions. These movements may be greatly increased by psychical factors. The involuntary passage of the intestinal contents as a result of fear is a familiar example. The commonest effect in neurotic individuals, however, is a partial or complete cessation of movements. The resulting stagnation of food leads to fermentation and putrefaction, even though the digestive fluids may be normal.

"I have a friend," said the manufacturer. "Hard-boiled business man. Has nausea, vomiting, headache for two or three days after every quarrel with his wife."

"In the same way, psychical, neurotic or hysterical factors may produce overactivity or underactivity of other internal organs, sufficient to cause serious symptoms. Hysterical suppression of urine, neurotic changes in heart action, psychical increase in internal secretions."

"How about hay fever?" asked the lawyer.

"A certain percentage is due to chemical idiosyncrasy. Abnormal chemical reactions on the nasal mucosa. Similar to the food idiosyncrasies we've already considered. In others, the symptoms are mainly, even solely of psychical origin. Patients who develop violent attacks on sight of a picture of a rose, for example. Or who develop symptoms at a certain definite date each year."

"That must account for the success of Christian Science with hay fever," said the manufacturer.

"There is no authentic case on record of hay fever due to chemical idiosyncrasy cured by any form of religio-therapy. There are authentic cures, however, of the psychical or hysterical form of the disease. This form is also cured by other methods. I know of a case. The pompous, neurotic patient so irritated his physician that he called him a 'Blankety-blank dam' fool. Get t'hell out of my office.' The patient became so angry that his symptoms disappeared."

"Hope the physician charged his regular fee," said the lawyer.

"The patient was a very wealthy broker. The physician sent

him a bill for a thousand dollars. This so increased his anger that his cure was permanent."

"You're surely joking," said the manufacturer.

"No. I was told this as an authentic incident in the life of Dr. Osler."

"Did he pay that bill?" asked the lawyer.

"I believe a check for a thousand dollars was eventually turned over to the charity ward of Dr. Osler's hospital."

6

"These neurotic changes are such simple things," said the lawyer. "Just overactivity or underactivity. Not at all what I was led to believe by my chiropractic friends."

"So far as biological science can determine, the only effect of psychical factors on an internal organ is either to stimulate the organ to excessive activity or to reduce its activity. There is no evidence of any other influence passing to the organ through the nerves."

"What about this 'life force'?" asked the lawyer.

"The nature of the nerve impulse has been the subject of serious research. There is no evidence that 'life force,' 'mental force,' 'spiritual influence,' or 'health-producing factors' are carried by the nerves. Your chiropractic friends were probably using highly figurative language, in the same way that you might say your chauffeur 'projected his personality' into your automobile, when in reality you mean he merely turned on or off the current going to the spark plugs, or otherwise varied its intensity or frequency."

"But they claim the energy of the organs comes from the brain," insisted the lawyer.

"I fear you have misunderstood their figurative language. You might as well claim that the energy moving your automobile comes from the battery supplying electricity for your ignition system. Certain organs even may function normally, after all nerves are severed connecting them with the brain. This is true of the heart. It merely loses the power of quickly adapting its rate to the varying needs of the body. If any practitioner really claims the energy of organs comes from the brain, it is through ignorance of biological facts. Or, a deliberate attempt on his part to deceive the public."

"Are these psychical or hysterical diseases sufficiently common to be of importance?" asked the manufacturer.

"Just what percentage of disease is caused by psychical or hysterical factors is hard to say. One physician told me that 25 per cent. of his patients were of the purely neurotic type. The

commonest picture, however, is an unimportant structural disease in one organ, with the resulting mild symptoms magnified by psychical or hysterical factors. Supplemented by purely psychical diseases or disturbances in other organs. Probably half of the symptoms with which patients complain are thus produced."

"Heavens!" said the lawyer. "What an inviting field for fakes!"

"There's easy money in it," said the manufacturer.

"With your legal knowledge," added the research worker, "you could easily put over any fake you found profitable."

IN AN OLD HEALTH-BOOK

By Dr. JAMES FREDERICK ROGERS

U. S. BUREAU OF EDUCATION

The earliest guide-books to health, published for popular reading in the English language, were given charming titles. How much more alluring, meaningful and withal dignified the "Castell of Helth," the "Haven of Health" or the "Myrrour or Glasse of Health" than "A Manual of Hygiene," "How to Keep Well," "The Human Mechanism" or the like dry-as-dust names stamped on the covers of our modern works of similar intent.

Nor is the meat of these books less interesting than the labels on their rinds, as we think the reader will allow after perusing the following fragments. However, this is already proven by the great popularity of these early books. We think we live in *the* age when health books are read with avidity, but few indeed of these modern works ever reach a second edition, while reprintings of works of a century or more since ran into the tens and twenties.

The "Castell of Helth" dates from the time when castles signified more than picturesque ruins. It first left the press in 1534 and was written by Thos. Elyot, Knight, Privy Councillor to Wolsey, an intimate of Cromwell and More, negotiator of divorces for Henry VIII, foreign diplomat and member of Parliament. This was probably the first attempt to render the teachings of Galen and other of the ancients into the vernacular and was looked upon as a double sacrilege in that this meddler with the language of medical science was a layman. Notwithstanding the fuming and scoffing of the profession, or because of it, the public read it gladly, and it soon became a best seller.

The "Haven of Health" appeared just fifty years later, at the time when Shakespeare's earlier plays were leaving the press. The author, Thomas Cogan, was in humble station, being a physician and master of a grammar school. This was not a bad combination for his pupils, and that he was deeply interested in the welfare of these young shoots he proved, not only by the writing of a guide to "The Haven of Health, made for the comfort of Students," but by bequeathing the sum of four pence (possibly all he possessed) to each boy in the school.

Cogan freely acknowledges his indebtedness to "Master Elyot his Castle of Health," but he displays more originality and independence of tradition. Medical science, like all science, still leaned

heavily on the ancients, and this Elizabethan hygienist divides his material according to the order of Hippocrates. However, he could hardly have done better, for the great Greek physician placed first in importance "labour, which in this place signifieth exercise of body and mind." And how refreshing to read here the wise words of Isocrates: "Use those exercises of the body which may rather preserve thy health than strength." As for mental exercises he advises students

to apply themselves earnestly to reading a meditation for the space of an houre; then to remit a little their cogitations, and in the meane time with an Ivorie combe to kembe their head from the forehead backwards about fortie times, and to rubbe their teeth with a coarse linen cloth. Then to return againe to meditation for two houres or one at least.

Such is the state of man and beast touching the body, that the spirites, humours, yea the sound substance of all parts doe continually waste and weare away. So that if by nourishment other like be not restored, of necessity the whole must shortly be consumed.

As fit fuel for keeping up the bodily energies Cogan recommends especially the flesh of the rabbit.

Conie which is so plentiful a meate in this Lande, and prooved so light of digestion, is little spoken of by Galen and other ancient writers. But it is verie well prooved amongst us, that there is no meate more wholesome or that more cleanly, firmely, and temperately nourisheth than Rabbettes. And what commoditie a good warraine of Conies bringeth toward the keeping of a good house, men both of honour and worship that love hospitalitie do very well know. Which vertue being acceptable unto God, and a singular benefite of all the Countrie round about them, (the more it is to be lamented) is every day more and more neglected in England. The chiefe cause thereof (us wisemen thinke) is waste-full and sumptuous apparell, now commonly used in everie degree farre otherwise than William Rufus did, who being a King's Sonne, and the second King of this Land after the Conquest, was thought to exceede, when he bestowed a Marke upon a paire of hose, using commonly to bestow but three shillings; whose example may well be a commendation to Gentlemen in these our daies, who bestow as much upon one paire of hose, as the King did upon twentie.

Here is a hint for those who need material pabulum for their organ of intelligence:

Pertrich of all fowles is most sooneth digested and hath in him much nourishment. It driveth away the dropsie, it comforteth the stomach, and it is said that customable eating of this flesh, comforteth the memory. Wherefore it were a convenient meate for Students, and such as be weake, and I would that everie good Student twice in a weeke in steade of his commons might have a Pertrich in his supper. Neither do I marvell considering the goodnesse of the flesh, that Gentlemen be at such cost to keepe Hawkes, and take such toyle to kill Pertriches and Fesaunts.

Of fish he remarks that

The Whiting for wholesomeness is well entertained in the Court of England, and is now became an old Courtier. . . . The Tenche is commonly called

the phisitian of other fishes, because when they are hurt thay are healed by touching of the Tenche, and as he is medicinable to fishes so is he wholesome to man's body. . . . The Troute is so sound in nourishing that when we would say in English that a man is thoroughly sound, we use to say that he is as sound as a Troute.

"Of henne egges the choice standeth in three pointes, that they be white, long, and new." Alas, there seem to have been stale eggs on the market in those prerefrigeration days.

He "reckons it a great treasure for a Student to have by him in his closet a pound of cinnamon steeped in a gallon of wine, to take now and then a spoonful."

"Much salt will make one to look old soone," but "I have known some maidens to drink vinegar nexte their hart to abate their colour and to make them faire."

"Beans," he says, "are meate for mowers and ploughmen but not for Students." Cheese will do for the diet of laboring men but not for students, for the latter "be commonly veletudinary, that is sickly. . . . As for roasted cheese, it is more meet to bait a trap, to catch a mouse or a rat, than to be received into the bodie."

Nutmegge which be hote and drie in the second degree not only maketh the mouth to savor well but they comfort the braine, the lights, the liver, the spleen, and especially the mouth of the stomach. In my judgment it is the best spice for students of all others.

The quantity of food to be taken was considered of the utmost importance by this sixteenth century physician. It "ought of all men greatly to be regarded, for therein lyeth no small occasion of health or sicknesse, of life or death. For as want of meats consumeth the very substance of our flesh, so doth excesses and surfet extinguish and suffocate natural heat wherein life consisteth." We can not put the matter more in a nutshell to-day, nor can we give higher praise to the art of cooking than in his words, "I mention cookes often times because coquerie is a part of Physicke and a good Cooke is halfe a Physician."

The greatest occasion why men passe the measure in eating, is varietie of meats at one meale . . . yea, the more we would welcome our friends the more dishes we prepare. And when we are well satisfied with one dish or two then come other more delicate & procureth us by that means to eat more than nature doth require. . . . The surest way in feeding is to leave with an appetite, according to the old saying, "& keep a corner for a friend!"

Fletcherism was forestalled by Cogan by three centuries or more:

To chew our meate and to swallow it down laysurely is a great furtherance to well digesting of the same. And indeede it is the verie end & purpose why the teeth were ordained.

We of the twentieth century like to pride ourselves on being the discoverers of the importance of prevention of disease. A glance at this book dispels such a notion. There are, however, some remedies offered for those who have kicked out of the traces of Nature's harness. If the reader suffers from the gout he may be glad to learn that

> an old Cheese is good for something, for Galen sheweth, that an old Cheese cut in pieces, and sodden with broth of a gambon of bacon, and after stamped with a little of the broth and made in a maner of a plaister, and layd to the joynt where the gowt is, will breake the skinne, and dissolve those hard knots which the gout causeth.

This recipe must have been read with much interest, for the sixteenth century was *the* age of the gout.

For toothache "Leekes and Henbane seedes burned together and the smoake received through a funnel into the mouth on that side which aketh, helpeth the toothache." "Feverfew, pounded and laid on the wrists, will cure ague in children," and "a decoction of walnut hulls will cure against pestalence."

> The Lungs of a Foxe are medicinable for them which have sicknesse of the Lungs, being used in this manner. Take the Lungs of a Foxe and drie it to powder, and put a quarter of a spooneful in a little almond milke, or broth, and eate it, for it is verie good to preserve the Lungs. . . .
>
> The haires of the Hare burned and applyed do staunch bloud, but chiefly the haires that grow under the belly, pulled off while the Hare is alive, and put into the nosethrilles, do stop bleeding at the nose.

Of course, "the anckle-bone of the foote of an Hare is good against the cramps."

Of sleep he says

> Let your lodging be in an upper chamber: let the bedsted be large and long, and no higher than a man may easily fall into it standing upon the chamber floore. Let the bed be soft, well shaken, and made rising up toward the feet, so that the bulke or breast of the bodie may be lowest. I remember when I was at Oxford in the second yeare of the raigne of her highnesse, one M. Atkins being for disobedience put in prison in London, had a chamber to himselfe, but no bed, and at length waring wearie of the bare boards: upon a night, having gotten a cudgegll or two, fell to beating and knocking of the floore, so long and so loude, that his keeper awaked, who in a rage comming to him, and demanding whether he were mad or no, that made such a noyse? "No for sooth Maister Keeper" (quote he) "I doe but beate my bed to make it soft if it would be, for it is so hard that it maketh my bones to ake!"

While we may smile at many of these Elizabethan remedies there is plenty of wisdom in Cogan's conclusion.

> That part of Physike is more excellent which preserveth health and preventeth sickness. For as much as health is the most perfect state of man's bodie in this life and the only end and marke whereunto the Phisition directeth

all his doings, which state to continue, which mark to hit, is much better than after we have fallen and erred, and missed, eftsoones to recover the same. Even as it is better to standfast still than to fall and rise againe, better to keep still a Castle or Citie, than after we have suffered the enemy to enter to rescue it again.

That the reader may better carry with him the lessons of the book the author sums his most important teachings in the following verse:

Ayre, labour, food, repletion,
Sleepe, and passions of the minde,
Both much and little hurt alike,
Best is the meane to finde.

In these five pointes as it were in so many Lute strings resteth the whole harmonie of man's life Wherein moderation beareth the burthen of the song.

No strings have been added to the lute of health since the days of Cogan, though they have been strummed vigorously, if less entertainingly, by hygienists in each generation; and in the twentieth, as in the sixteenth century, temperance is still their refrain.

THE CENTER OF POPULATION—A PROPHECY AND ITS FULFILMENT

By Professor WALTER CROSBY EELLS
WHITMAN COLLEGE

In *Scribner's Monthly,* the forerunner of the present *Century Magazine,* for June, 1872 (Vol. IV, p. 214), occurs an article "The advance of population in the United States," by Julius Erasmus Hilgard. This article has special interest for the scientific public to-day, due to the fact that it is exactly fifty years since its author was elected president of the American Association for the Advancement of Science. In this article that talented engineer and brilliant scientist made the first reliable computation of the center of population of the United States, and ventured a half dozen remarkable prophecies as to its future course. The recent publication of a special bulletin of the national Census Bureau, "Center of population and median lines and center of area," gives data from which it is possible to show to what a remarkable extent these predictions of Hilgard, made over a half century ago, have been fulfilled.

The first official computation of the point known as the *center of population* was made under the direction of Francis A. Walker, superintendent of the ninth census and also professor of political economy and history in the Sheffield Scientific School of Yale University. It was made expressly for publication in the first statistical atlas of the United States, which was published in 1874, and based upon the results secured in the ninth census, that of 1870. The center of population was computed laboriously for each census date since 1790, except for those of 1840 and 1850. These, although he computed them by a somewhat different method, were taken from Hilgard's article mentioned above.

Without attempting to reproduce Hilgard's tables and map, it is interesting for the present generation to read again the more significant paragraphs from his article.

The decennial inventory of the nation forms an almost inexhaustible source from which the statistician and political economist may draw information concerning the development of the country as to its population, wealth and industry in their most varied aspects. . . .

In order to get some measure of this advance, or some general idea of the rate at which the country is filling up, we will consider the centers of population at different periods and examine their progress.

If the population of a country were uniformly distributed, the center of population would coincide with the geographical center, being the point upon which the area may be said to balance. . . . The center of population may be defined as the center of gravity of the population, it being, in fact, the point

in which the area, loaded with its population, each man in his place, would balance. . . .

We shall furthermore observe, before proceeding to the actual case in hand, that when the tendency is to a uniform distribution of the population, the excess of increase in the new country over that in the old settlements will in time diminish, and that therefore the approach of the center of population to that of area will proceed at a constantly lessening rate. Without entering upon an elaborate discussion of this proposition, it will suffice to say that the resulting law will not differ essentially from a movement of the center of gravity of population toward its ultimate limit, in a nearly constant ratio of the remaining distance—that is to say, if within a given period the center of gravity has advanced toward its permanent place by one fourth part of the distance at the beginning of the period, it will in an equal period next succeeding advance over one fourth of the remaining space, and so on, always assuming that the movement of population is not affected by any extraordinary disturbances.

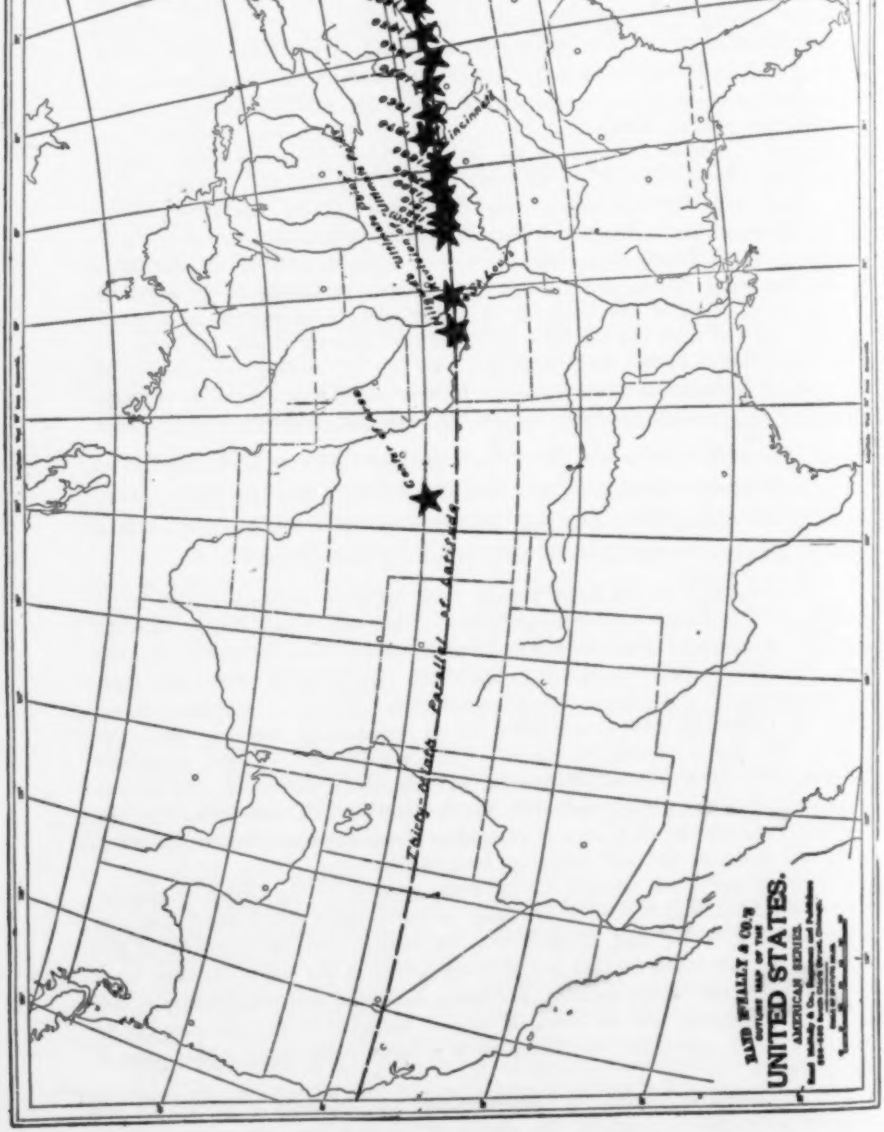
Let us now turn to a map of the United States. Its geographical center is just below the middle of the northern boundary of Kansas. Owing to the comparative infertility of the territory lying west of the meridian passing through that center, it is certain that the center of population, when a permanent ratio of distribution shall have been reached, can not lie far west of the Mississippi River; and since there is no great disparity in the northern and southern zones of the territory as to their power of sustaining a population, it will be near the middle latitude of 39°, placing it not far from the city of St. Louis, as has been claimed by persons advocating the removal of the seat of government to that place. In what time that condition is likely to be reached, we shall presently endeavor to show our readers how to estimate.

Hilgard then gives the exact location, by latitude and longitude, of the center of population, as computed by him, for the years 1840, 1850, 1860 and 1870. On this rather narrow basis he generalizes and prophesies as outlined in the following paragraphs:

The advances in the three periods were fifty-five, eighty-two and forty-six miles. The comparatively large stride during the second decade and the checked advance and more northerly direction in the third at once strike the eye. The former is attributable to the rapid settlement of California after the discovery of gold, by which a considerable population was transferred from the eastern half of the country, to its westernmost regions; the latter exhibits the loss in the rate of increase occasioned by the Civil War, especially in the South. We may safely assume that disturbing causes of such magnitude can not occur again, and that the progression will show hereafter but slight fluctuations from a regular law, since those extraordinary events have, after all, produced but very moderate inequalities.

Placing now, at a venture, the ultimate position of the center of population 600 miles to the west of its location in 1840, which will bring it between fifty and sixty miles west of St. Louis, we observe that the advance of 180 miles in the last three decades is just three tenths of the whole distance, leaving 420 miles still to be gained. But three tenths of this remaining distance is 126 miles, which may be taken as a good estimate of the advance during the next thirty years, and will bring us to a point some thirty miles south of Indianapolis.

Not wishing to stretch our inferences too far, we leave it to such of our readers as choose to perform the simple calculation for subsequent periods,



MAP SHOWING MOVEMENT OF CENTER OF POPULATION

At the time of Hilgard's predictions the positions of the center of population for 1790, 1800, 1810, 1820 and 1830 had not been computed.

which will lead them to the result that in the year 2000 the center of population will still be lingering in Illinois, some thirty miles east of St. Louis. However that may be, it is certainly safe to predict that in 1880 our center will be about 10 miles north of Cincinnati.

The Prophecies Summarized

The extracts quoted above contain the following very striking predictions:

(1) The center of population will remain near the thirty-ninth parallel of latitude.

(2) Great disturbing facts like the settlement of California (1850–1860) and the Civil War (1860–1870) are not likely to occur again.

(3) The center of population will advance in accordance with a regular law, by which in 1900 it will have moved 126 miles westward and by the same law in 1930, 88 miles farther west.

(4) In the year 2000 it will be about 30 miles east of St. Louis.

(5) In 1880 it will be 10 miles north of Cincinnati.

Fulfilment of the Prophecies

It is of great interest now, a half century after these predictions were made, to see how very strikingly they have been fulfilled.

(1) The closeness with which the center of population has clung to the thirty-ninth parallel is very remarkable. The point farthest north was reached in 1790, and the point farthest south in 1830, but the entire difference was only 21.4 miles. The farthest north since the date of Hilgard's prediction was in 1890, when it was 13.7 miles north of the thirty-ninth parallel. It has kept slightly north of the thirty-ninth parallel at every census since 1850, varying from 4.7 miles in 1880 to 13.7 miles in 1890. In 1920 it was 11.9 miles north of the thirty-ninth parallel. In 1920 it was only two miles north of its position in 1870, the latest available date in Hilgard's article.

(2) This has also been verified. The westward advance from 1850 to 1860 was about 50 per cent. greater than in any other decade, before or since; and the northward advance from 1860 to 1870 was also 50 per cent. greater than in any other decade.

(3) This is perhaps the most daring and unique of all Hilgard's predictions, since it attempts to put everything into a fixed mathematical formula. In the thirty year period from 1870 to 1900 the center of population actually advanced westward 120 miles, or 119.5 miles, to be more exact, instead of the predicted 126—a very small error indeed.

Applying Hilgard's method of moving three tenths of the distance remaining to the "ultimate point" (600 miles west of the

position in 1840), it is found that it should have moved westward three tenths of 294 miles, or 88 miles, between 1900 and 1930. In the two thirds of this period from 1900 to 1920 it has moved only 49 miles, or ten miles less than two thirds of the predicted distance.

But Hilgard's choice of a point 600 miles west of the 1840 position was somewhat arbitrary. It will be noted that he himself qualifies it by the phrase "at a venture." In the light of subsequent developments a slightly different choice of location for the "ultimate point" (to which identically the same method would apply) can be made with a slight improvement. The solution of a simple set of equations shows that if Hilgard has assumed "at a venture" a distance of 540 miles, instead of 600 miles, and then on the basis of the movement from 1840 to 1870 of 180 miles, had taken *one third* as a constant multiplier instead of *three tenths,* he would have come even closer to the actual conditions as far as they are known fifty years later.

With this slight change of constant distance, it works out thus:

1840–1870: One third of 540 miles = 180 miles.
Actual distance, 180 miles.
1870–1900: One third of 360 miles = 120 miles.
Actual distance, 119.5 miles.
1900–1930: One third of 240 miles = 80 miles.

Two thirds of this last movement of 80 miles is 53 miles, as compared with 49 miles, the distance actually travelled from 1900 to 1920. The chances seem good that it may move the remaining 31 miles during the present decade.

This revised "ultimate point," 540 miles west of the 1840 position, would be practically on the meridian of St. Louis, instead of 50 or 60 miles west of it, and thus would come even closer to making that city the logical seat of government. If it is placed on the thirty-ninth parallel, it would be about 25 miles north of St. Louis, in the southeastern part of Jersey County, Illinois.

(4) Of course the prediction regarding the position in the year 2000 can not yet be verified. But continuing the above suggested revision of Hilgard's principle, we have the following predictions until the year 2020:

1930–1960: One third of remaining 160 miles = 53 miles.
1960–1990: One third of remaining 103 miles = 34 miles.
1990–2020: One third of remaining 69 miles = 23 miles.

These results indicate that in 1990 it would probably be about 70 miles east of St. Louis, and in 2020, about 46 miles east. Hilgard's prediction of 30 miles east in 2000 may therefore be allowed to stand, with only slight modification, for another half century or more.

(5) It is rather surprising that Hilgard's final prediction of the situation only eight years after the publication of his article,

which he naturally makes with the greatest confidence, should actually have proved relatively his poorest forecast. As a matter of fact, instead of being 10 miles north of Cincinnati, it was south and west of that city by 8 miles, across the Ohio River in Kentucky. It is evident that Hilgard was justifiedly misled by the fact that from 1860 to 1870 the center of population moved northward 13 miles, a greater northward movement than ever before or since, until it was in the same latitude as Cincinnati. It was quite natural to suppose that in the next decade it would continue northward ten or twelve miles more. But its sudden jump northward was apparent rather than real, partially at least due to an inadequate enumeration. The census bureau explains it in part by the waste and destruction in the south from the Civil War, and in part (perhaps more important), to the acknowledged fact that the census of 1870 was very defective in its enumeration of the southern states, especially of the newly enfranchised negro population. That its sudden northern movement was thus fictitious rather than real is also indicated by the fact that it returned southward nine miles in 1880, when the enumeration was equally accurate in north and south.

Who Was Hilgard?

A few facts concerning this almost forgotten scientist, who succeeded so remarkably in his prophecies regarding the center of population when it was practically a virgin and untried field, may be of interest to the reader to-day.

He was born in Bavaria in 1825 but came to Illinois with his father's family when only ten years of age. He began his study of engineering in Philadelphia in 1843 and two years later entered the service of the Coast Survey under the distinguished Bache. This was the beginning of an honorable career of merit and ability with this organization lasting for over forty years and culminating all too tardily in his appointment as superintendent of the survey in 1881, a position which he held for four of the declining years of his life.

Starting as a temporary employe in field service, in the twenty years preceding the Civil War, under the magnetic encouragement of his chief, he came to occupy successively positions of greater trust and responsibility. He was a careful scientific student, as well as a successful executive. He was enthusiastic, an indefatigable worker, alert in the recognition of all that was valuable in new methods, and from his linguistic ability and wide reading thoroughly informed on the progress of geodesy and engineering both at home and abroad.

Under the stress of the Civil War, the Coast Survey was called upon for heroic and invaluable service in connection with southern

coast surveys and charts. The direction of the work was heavy, responsible and incessant; the anxiety, watchfulness and care were said to be as wearing on the chief as those of the commander of an army corps. Under this terrific strain the brilliant Bache's mind gave way, and double responsibility fell to his principal assistant, Hilgard, who met every requirement of the difficult position with credit and distinction.

After the breakdown of his chief, Hilgard might have had the superintendency for the asking, but he refused to ask for it as long as his broken chief lived, since the family of Bache were in such circumstances that his salary was necessary for their support. This disinterestedness and loyalty to his chief cost him dear. Bache lingered through four weary years, and when death finally took him there were several strong rival candidates in the field. After a prolonged struggle it was considered wise to appoint a "dark horse," Benjamin Peirce, of Harvard University, "the father of American mathematics."

It was not until 1881, after a lifetime of sacrificial and distinguished service, that Hilgard was finally appointed superintendent of the Coast Survey. He was then broken in health and suffering from the invasion of his household by death. The appointment seemed to give him new life, but it proved to be only a temporary stimulus. His working days were about over. Under the unfortunate political changes of 1884 he was compelled to sever his relations with the organization to which he had devoted a lifetime of loyal service. It was a crushing blow. Suffering with illness all the time, he never regained his health, although he lingered on until death finally came in May, 1891.

In 1862, in addition to his heavy work in the Coast Survey office, he was also supervisor of weights and measures for the treasury department. He was one of the members of the Metric Commission at Paris in 1872 and was made a member of the permanent committee. He took a leading part in preparing exact metric standards for distribution to the various states and territories. He was a member of the International Bureau of Weights and Measures, of which he declined the directorship. Typical of his many scientific contributions, may be mentioned one on the telegraphic determination of differences in longitude of Greenwich, Paris and Washington.

He was a charter member of the National Academy of Sciences and for some years its home secretary. In 1874 he was given distinctive recognition by his fellow-scientists when they elected him president of the American Association for the Advancement of Science.

THE BACONIAN METHOD OF SCIENTIFIC RESEARCH[1]

By Professor FLORIAN CAJORI

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THE Baconian method of scientific research has been appraised in the language of superlatives. On the one hand is the statement of J. G. Hibben:[2] "The revolt against the scholasticism of the Middle Ages and the fetters of the Aristotelian logic was many-voiced, culminating, however, as regards the emphasis placed upon induction as a scientific method, in the works of Francis Bacon." Similarly, T. Fowler[3] writes: "Inductive logic, that is, the systematic analysis and arrangement of inductive evidence, as distinct from natural induction which all men practice, is almost as much the creation of Bacon as deductive logic is that of Aristotle." J. Playfair[4] says: "The power and compass of the mind which could form such a plan beforehand and trace not merely the outline but many of the most minute ramifications of science which did not yet exist must be an object of admiration to all succeeding ages." Likewise, Macaulay[5] writes: "The *Novum organum* takes in at once all the domains of science—all the past, the present and the future, all the errors of two thousand years, all the encouraging signs of the passing times, all the bright hopes of the coming ages." Bacon "moved the intellects which have moved the world."

On the other hand, the weakness of the Baconian procedure is pointed out by Hibben[6] thus: "Bacon has no recourse to deduction based upon hypothesis and consequent verification. He seems to despise mathematical method as an ally of inductive inquiry and therefore has no place in his scheme for the prediction of new phenomena by means of calculation." According to the chemist, J. Liebig,[7] "Bacon meant therewith experiments which one undertakes without knowing what one is seeking, they are endeavors to

[2] J. G. Hibben, "Inductive Logic," Edinburgh and London, 1896, p. 300.

[3] T. Fowler, Art., "Bacon, Sir Fr.," in the *Dictionary of National Biography.*

[4] J. Playfair, in Encyclop. Britannica, Edinburgh, 1843, 7th Ed., Vol. I, pp. 16–17; "Dissertations," London, 1835, "Dissertation Third," p. 468.

[5] T. B. Macaulay, Essays, 1855, Vol. II, pp. 142–254 (*Edinburgh Review*, July, 1837); "Miscellaneous Works of Lord Macaulay," Vol. 2, New York, 1880, pp. 455, 456.

[6] J. G. Hibben, *op. cit.*, p. 306.

[7] Justus von Liebig, "Ueber Francis Bacon von Verulam und die Methode der Naturforschung," München, 1863, pp. 11, 47, 48.

compare without the motive therefor, and their results are therefore purposeless and aimless." "The true method does not progress, as Bacon would have it, from many cases, but from a single case; when this is explained then all analogous cases are explained; our method is the old Aristotelian method, only applied with immensely greater skill and experience. . . ." "The result reached by his method is always zero." "Such a procedure can never lead to discovery of truth." "The real method of natural science excludes chance (Willkür) and is diametrically the opposite of Bacon's method." Such is the dictum of the great German chemist. The famous astronomer George Howard Darwin[8] declares: "A mere catalogue of facts, however well arranged, has never led to any important scientific generalization. For in any subject, the facts are so numerous and many-sided that they only lead us to a conclusion when they are marshalled by the light of some leading idea. A theory is then a necessity for the advance of science." In the same vein writes the mathematician Augustus De Morgan:[9] "Bacon himself was very ignorant of all that had been done by mathematics. . . . He especially objected to astronomy being handed over to the mathematicians. . . . If Newton had taken Bacon for his master, not he, but somebody else, would have been Newton." Again we quote Liebig:[10] "The overthrow of scholasticism by Bacon was the warfare of the famous Knight with windmills."

Sir Oliver Lodge[11] writes: "He was not a scientific man, and his rules for making discoveries, or methods of induction, have never been consciously, nor often indeed unconsciously, followed by discoverers. They are not in fact practical rules at all, though they were so intended."

Such great praise and censure must signify great merits and great defects. Whichever view we adopt, one thing is clear, Bacon ranks as the earliest prominent methodologist of scientific inquiry. He represents an effort to proceed beyond the crude and slovenly inductive procedure of simple enumeration of affirmative observations. Bacon insists that men should mark when they miss as well as when they hit; they should observe many cases—the more the better. He compares his method to a pair of compasses which enables any beginner to draw a perfect circle. In his "Solomon's House" all intellectual ranks are able to contribute to discovery in

[8] G. H. Darwin's Presidential Address, *Report of British Association*, 1886, p. 511.

[9] A. De Morgan, "A Budget of Paradoxes," Chicago, Vol. 1, 1915, pp. 82, 84.

[10] Liebig, *op. cit.*, p. 55.

[11] O. Lodge, "Pioneers of Science," London, 1905, p. 136.

science.[12] His method was designed to be so perfect that genius seemed superfluous.

Needless to say that Bacon's method did not stand the test of experience. The two contributions to science made by Bacon himself were not made by his own method; they partook really of the nature of hypotheses. Bacon held the view that heat was a mode of molecular motion, and that in biological study, living objects are well adapted to experimental work, for the artificial production of variation.

Scientists seldom indulge in introspection when engaged in research. In the seventeenth century the scientific method formulated itself in the actual pursuit of scientific investigation. The method was not so much thought out as it was worked out. The Baconian method proved itself insufficient, being too narrow. The use of hypotheses and deductive reasoning was freely employed. The methodology of science, as stated by Bacon, needed revision, enrichment. This was undertaken by John Stuart Mill, who assigned to hypotheses their legitimate place. But even Mill's methodology lacks completeness. In the expositions of their methods, both Mill and Bacon understated the importance of mathematics, and of exact measurement. Neither provided a place for mathematical physics. Perhaps both also underrated the great rôle of the scientific imagination, the importance of which has been brought out so strongly by Tyndall and recently by Rutherford.

The methodology set up by Bacon is often quite necessary in a research, but is seldom sufficient. Few research men have altogether avoided it; few have limited themselves to it. Since it has been asserted by some critics that Bacon's method is useless and absurd, it may be worth while to point out cases where it has played a leading rôle. In zoology,[13] where, from Aristotle to Darwin, the main function was classification, Aristotle introduced species and varieties. Linnaeus introduced four groups, *viz.*, classes, orders, species and varieties; he divided the animal kingdom into six classes: Mammalia, birds, reptiles, fishes, insects and worms. Then came Cuvier, the founder of comparative anatomy, who divided animals into only four classes: Vertebrates, mollusks, articulates and radiates. The fundamental idea emphasized by both Cuvier and Agassiz is comparison, searching comparison. Similar remarks apply to the development of botany. In all this work the observation of resemblances and differences, the classification into groups, is the predominant feature. Substantial progress

[12] Fr. Bacon's "New Atlantis," *Works of Francis Bacon*, Vol. I, Philadelphia, 1850, pp. 255, 262 ff.

[13] See L. Agassiz, "Methods of Study in Natural History," Boston, 1869, pp. 3–23.

was slow. Then came the work of Charles Darwin. During his early studies Baconian methodology prevailed. He himself says:[14] "I worked on true Baconian principles, and without any theory, collected facts on a wholesale scale." Then, after many years of preparation, Darwin came forth with one of those great hypotheses which occasionally appear in the history of science—his hypothesis relating to the origin of species and the descent of man. It infused extraordinary vitality into all fields of biology. Sir Edwin Ray Lankester's characterization of these periods is as follows:[15] "We may be thankful that at the present day we are not likely, in the domain of biology, to make the mistake (which has been made under other circumstances) of substituting the mere inspection and cataloguing of natural objects for that more truly scientific attitude which consists in assigning the facts which come under our observation to their causes, or, in other words, to their places in the order of nature. . . . All true science deals with speculation and hypothesis, and acknowledges as its most valued servant— . . . the imagination."

The Baconian method was predominant in the work of Alexander von Humboldt who, in the words of Agassiz, had a "broad knowledge of all nature" as had no other naturalist. We shall not now examine Schiller's stricture that the great naturalist lacked imagination. We observe, however, that with him hypotheses were very secondary, the passion of his career was collection of facts, description and classification. It was not his lot to advance hypotheses like that of the conservation of mass or of energy, yet who will say that Humboldt's "Kosmos" does not occupy a place of honor in the history of science?

While Bacon's method has been widely applied in biology, its use in astronomy and physics, and in other sciences which admit the extended use of mathematics, has been less prominent. In experiments on the spectral colors, Newton consciously or unconsciously used Bacon's method in part, though he also advanced hypotheses, some of which he rejected. He studied the phenomena under a variety of different conditions. If in one case it had been his good fortune to push the Baconian process one step further, the achromatic lens of the refracting telescope would have been invented in the seventeenth century, instead of the eighteenth. Newton supposed that all transparent bodies when shaped into prisms produced prismatic spectra of equal length upon a fixed screen. If he had tested this assumption by careful experiments, he would

14 "Life and Letters of Charles Darwin," Vol. I, p. 83.

15 Sir Edwin Ray Lankester, "The Advancement of Science," London, 1890, p. 4.

have noticed that it was false and would have been prepared to improve the refracting telescope.

An interesting application of the Baconian method, exhibiting its importance as well as its limitation, is found in the study of the aurora borealis. Among those who published observations of this strange phenomenon was Isaac Greenwood, the first Hollis professor of mathematics and natural philosophy at Harvard College. Greenwood observed the brilliant aurora borealis of 1730 at Cambridge. "I am persuaded," he says,[16] "there is no better way to arrive at the true Cause of this extraordinary Phenomenon, than by attending to the minutest Particulars and Circumstances thereof, and if what I have done contributes thereunto, I shall esteem it a sufficient Excuse for the Number and Particularity of my Notes." He took great care to record observations on temperature, wind, dew, hoarfrost, barometric pressure, time of rise and decay of the auroral displays, their color-effects, the angular altitude of the streamers, etc. But the number of possible observations is unlimited, and it did not occur to Greenwood to observe the behavior of the compass needle. Before this, Halley had noticed that the summit of the aurora lay in the magnetic meridian. In 1741, O. P. Hjorter saw by accident that during auroral displays the magnetic needle was in violent agitation; Mairan observed that the dipping needle pointed directly to the spot to which the auroral rays converge. These magnetic observations were simply a few in a large mass of miscellaneous observations. In the absence of a theory connecting the aurora borealis with magnetism they meant but little. There existed no criterion for the selection of those that were vital. Among the first to form a hypothesis was Benjamin Franklin. He had advanced his one-fluid theory of electricity during the first year of his study of electricity. He called that fluid "electric fire." In a letter to Peter Collinson,[17] he makes the guess that the aurora borealis is an electric phenomenon. He says: "When the air, with its vapors raised from the ocean between the tropics, comes to descend in the polar regions, and to be in contact with the vapors arising there, the electrical fire they brought begins to be communicated, and is seen in clear nights." Four years later he expressed himself in greater detail. Franklin's theory that the aurora is due to electric discharges in the upper air has maintained its place to our time. One can not read Franklin's scientific writings without being impressed by the extraordinary play of his imagination. When an old man, he[18] once wrote to James Bowdoin: "Our most

[16] *Philosophical Transactions*, Vol. 37, London, p. 55; Abridged, Vol. VI, Part II, pp. 115–121.

[17] "The Complete Works of Benjamin Franklin," by J. Bigelow, Vol. II, 1887, pp. 146, 253.

[18] "The Complete Works," etc., Vol. 9, p. 473.

regretted friend Winthrop once made me the compliment that I was good at starting game for philosophers; let me try if I can start a little for you." In the case of Franklin the use of hypotheses was second nature.

Franklin does not seem to have been familiar with the behavior of the magnetic needle during auroral displays. In fact, he had no intimation of the interrelation of electric and magnetic phenomena. In more recent time, Arrhenius advanced a much more comprehensive hypothesis, implicating our great solar luminary. We have here a fine example of how in the early stages of investigation the Baconian method was followed and how, before the time of Franklin, investigators made numerous observations, but possessed no guiding principle whatever. The Baconian procedure was necessary but not sufficient.

A fairly close approach to the Baconian method was made at one time by the chemist, Wilhelm Ostwald. Toward the end of the last century he deliberately took a "turn toward Energetic and thereby toward liberation from hypothetical conceptions which (as he said) led to no immediate, experimentally verifiable conclusions." He abandoned the atomic and molecular theories,[19] "jene schädlichen Hypothesen" mit "Spitzen und Haken an den Atomen," and took up the more direct study of experimental facts and of the resulting graphic charts. This is a striking example of theories discarded by one great worker as hopelessly misleading—theories which led other workers to the richest nuggets of new truths.

The study of earthquakes is at present in a stage where the Baconian method finds repeated application. Irregular movements of certain peaks and lighthouses in the coastal region of northern California have been revealed by careful surveys and observations which, it is said, may lead to rough predictions of the time and place of earthquakes. Seismic surveys of the world have been under way during the present century. Data are being gathered relating to double and multiple earthquakes, and relating also to the synchronism of seismic activity in different regions.

Periodigrams of earthquake frequency have been constructed. From such data it has been concluded[20] that "one megaseism may . . . cause a relief of seismic strain throughout the world," that no period of from seven to twenty years existed. These are results arrived at by the Baconian method, but of course hypotheses play an important rôle in the deeper study of seismic phenomena.

It is of no little interest that the forecasting of the weather is

[19] Wilhelm Ostwald, "Ueber Katalyse," 2, Aufl., Leipzig, 1911, pp. 25, 26. See also Ostwald's Faraday Lecture in *Nature*, Vol. 70, 1904, p. 15; Preface to Ostwald's "Fundamental Principles of Chemistry," translated by H. W. Morse.

[20] *Nature*, Nov. 23, 1911, p. 124.

done to-day by strictly Baconian processes. Each morning several hundred of our weather bureau stations telegraph their meteorological observations. Then charts are prepared showing the change in temperature and in barometric pressure for the preceding twenty-four hours—also a general weather chart showing for each station the air temperature and pressure, the velocity and direction of the wind, the rain or snow fall and cloudiness. The forecaster notes the position of each cyclone or anticyclone and with the aid of previous charts determines their speed and direction, and predicts the events of the weather for the immediate future. It has been suggested that perhaps Swift's satire[21] on pretended philosophers who operated by the preparation and mechanical manipulation of charts was directed against Bacon's method of making discoveries by means of huge synoptic tables constructed by clerks. As a matter of fact the United States bureau conducts its forecasting along the very lines proposed by Bacon and seemingly ridiculed by Swift.

As an example of a research which led to truly important results by the use of the Baconian method alone, H. H. Turner,[22] of Oxford, has cited the work of W. W. Campbell, at the Lick Observatory, on the velocities of heavenly bodies in the line of sight, published in 1911.[23] Campbell undertook the measurements of radial velocities of stars without the guide of any hypothesis. He believed that the outcome in some way would be for the advancement of science. And indeed the classification of the results of ten years' measurements led to the capital discovery that the older a star is the quicker it moves. "The stellar velocities increase rapidly, on the average, as we pass from the blue stars through the yellow stars and on to the red stars."[24] The result was quite unexpected; it was confirmed by the researches of Kapteyn.

In view of what has been said, it appears that many, if not most, of the appraisals of the Baconian method are not in accordance with the actual facts. Bacon did not initiate a new era in experimental science. On the other hand, his method has played a significant rôle in scientific progress. The facts support the statement that Sir Francis Bacon was a herald of the dawn of experimental science, that he ranks as the first great methodologist of experimental research, that his method does not fully describe the processes usually followed by men engaged in actual research, but represents as a rule only the preliminary stages, and that in some few instances the exclusive use of his method has led to far-reaching results.

[21] J. Swift, "Gulliver's Travels," Works, Vol. 2, New York, "Voyages to Laputa," Chap. 2, pp. 133, 138.

[22] H. H. Turner, Address, *Nature*, Vol. 87, 1911, p. 290.

[23] *Lick Observatory Bulletin*, Vol. 6, No. 196, 1911, pp. 125–135.

[24] *Proceedings of the National Academy of Sciences*, Vol. 1, 1915, p. 8.

THE GLOW OF PHOSPHORUS[1]

By LORD RAYLEIGH

THE discovery of phosphorus was one of those which is associated with the transitional period when magic and science flourished to some extent side by side, and when the borderline between them was not very well defined. It seems to have been discovered by the alchemist Brand, of Hamburg. But in those days scientific discoveries were often cherished as valuable secrets, not so much for their commercial value as for the sense of superior knowledge and power which their exclusive possession was supposed to give. Scientific secrets are sometimes jealously guarded now, but not for this reason. When reticence is observed it is for the less romantic motive of commercial advantage. In the absence of this motive, the scientific men of to-day tell all they know, and tell it without delay.

The subject of phosphorus emerged into daylight in 1678, when Kunkel, who had learned the secret by word of mouth, made it public. In 1780 the Hon. Robert Boyle deposited a paper on the same subject with the Royal Society. He had worked it out anew, without more than the hint that phosphorus came from an animal source.

It was a long time before the nature of the luminosity of phosphorus was finally settled. The early investigators not unnaturally classed it with the substances which become luminous by exposure to light, such as impure calcium sulphide. This notion survives in the word "phosphorescence," which is after all purely descriptive of the property of giving light. Now, however, the word is usually reserved for the cases like calcium sulphide. Phosphorus is not commonly spoken of as phosphorescent; its luminosity, as every one now knows, is due to slow combustion in the oxygen of the air. It took a long time to prove this, and the question was still in a measure open down to the year 1874. The doubt arose partly from the extremely small quantity of oxygen necessary to make the phosphorus visibly luminous. Accidental leakages may thus confuse the question. Another puzzling circumstance was that when oxygen was substituted for air the glow was extinguished. This made it difficult at first sight to defend the position that oxygen was what was wanted to make the phosphorus glow. I have sometimes thought that it might make a plausible argument for the home-

[1] Address before the Royal Institution of Great Britain, June 6, 1924.

opathist. The less oxygen you put in the more effect it seems to have. I will show you this. We have here a large flask of 4-liter capacity. There is phosphorus on the bottom, and in order to dissolve some of the phosphorus and distribute it over a large area some olive oil has been placed on it. I can swill this oil over the surface, so that it covers a large area. At present the flask is full of oxygen, and when the lights are extinguished you can see that the phosphorus is quite dark. We will now remove some of the oxygen by means of an air-pump, and you can see that the phosphorus suddenly blazes out at a lowered oxygen pressure. The same result may be shown by substituting air for oxygen.

This is not the only peculiar thing about the behavior of glowing phosphorus. I will show you another. I have here a glass dish, with the oily solution of phosphorus which was used before covering the bottom. I remove the cover, and agitate it well, so as to bring the phosphorus in contact with air and get vigorous oxidation and a good glow. I now hold above it a piece of cotton wool moistened with bisulphide of carbon. I do not squeeze the cotton wool so as to allow liquid drops to fall from it. I merely hold it loosely, so that the vapor can stream down from it on to the glowing surface. You can see that this vapor has an almost magical effect. It stops the phosphorus glowing altogether. If we allow a little time, the small quantity of vapor gets dissipated, and the phosphorus glows again.

Bisulphide of carbon is only one example of many vapors which will behave in this way. Ammonia, camphor, ethylene, turpentine and essential oils generally will do the same thing, though they vary widely as to their effectiveness. The majority of permanent gases have little effect in this way, though I am not prepared to say what they might do at high pressures.

It will probably be admitted on consideration that the action of oxygen, which I showed you at first, is not essentially different from that of the other inhibiting substances. As will be explained shortly, the action occurs between oxygen and phosphorus vapor. A little oxygen is necessary to unite with the vapor as it comes away from the phosphorus surface, but the density that is of any use in this way is very small. If, for instance, we have a millimeter of oxygen pressure there will be in the gas space many oxygen molecules for one phosphorus molecule, and a further increase can hardly promote the combustion. The action of a great excess of oxygen, as when we admit it up to atmospheric pressure, must be something quite different. There is therefore no real paradox in the quenching by an excess of oxygen. Perhaps this analogy may help to explain what I mean: A man can not live without water; if he does not get

it he will die of thirst; yet if he swallows too much he may be drowned. The water acts in quite different ways in the two cases, and so does oxygen in contact with phosphorus.

Another very strange thing happens when phosphorus is used to get rid of the last traces of oxygen in gas analysis. Suppose that we start with air in a confined space, and put a piece of phosphorus into it. At first the light is confined to the surface, but as the oxygen approaches exhaustion, the light is seen to become diffused throughout the volume of the vessel. It is easy to understand why this happens. Phosphorus is appreciably volatile at the ordinary temperature. When the surrounding oxygen is abundant it snaps up the phosphorus vapor at once, before it can diffuse away from the surface. But when oxygen becomes scarce the phosphorus has the chance to get some distance before this happens. This much is easy to understand. But if we look closely we see that the glow is not steady, but shows moving clouds of luminosity, most curious to watch.

Unfortunately, this experiment is too faint for an audience. But any one can readily try it for himself. Nothing more is required than a piece of phosphorus stuck on a wire and introduced into a bottle—say, an ordinary bedroom decanter—which stands inverted with its neck under water.

My own work on the subject started from this experiment, which I tried to develop into something more definite than clouds of vague outline moving in an ill-defined path. The slide (Fig. 1) shows an attempt in this direction which had some success.

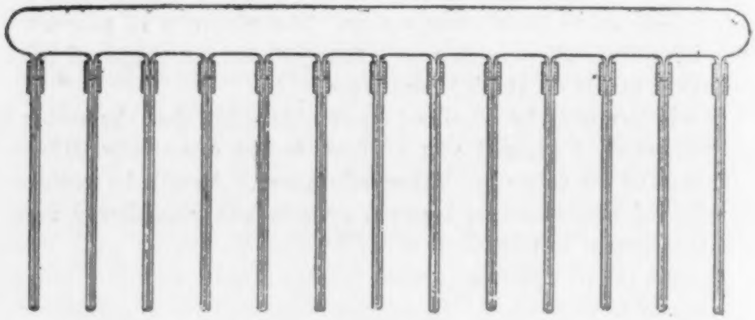


FIG. 1

The idea was to constrain the luminosity to move in one direction only. The horizontal tube has a layer of phosphorus lying along the bottom. The long narrow vertical tubes allow air to slowly leak in. When the oxygen originally in the tube is nearly exhausted, luminous pulses are seen to spring into existence at the side openings, to divide and to travel along the tube. Usually this happens

predominantly at one or two particular places. Pulses travelling along the tube in opposite directions kill one another when they meet.

I set up this arrangement in a dark room, and watched it from time to time. The experiment is so fascinating that one is tempted to waste a good deal of time in doing this. But after the lapse of a week or more a change was noticed. Although nothing had been touched, the movements were less lively, and the light had become stationary in places. Finally, all movements ceased.

What could be the explanation of this? The phosphorus had originally been melted into the tube under water, for safety, and the water was as far as possible poured off. But, of course, it could not be got rid of completely in that way. The oxides of phosphorus produced by the combustion are greedy of water, and thus had gradually dried the tube. On adding water the movements began again.

The next slide (Fig. 2) shows a similar tube, with only one capillary entrance at the middle. It was dried out on the mercury pump in the first instance, and filled with nitrogen. A perfectly

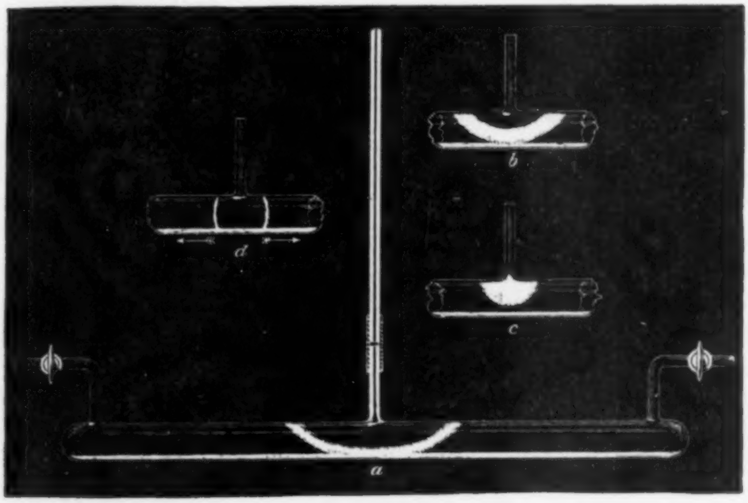


Fig. 2

steady cloud of luminosity is seen when atmospheric oxygen begins to mingle with phosphorus vapor. *a*, *b* and *c* show successive stages as the oxygen influx is increased. If a drop or two of water is added we get a succession of luminous pulses starting up at the side entrance, dividing and travelling in opposite directions along the tube (Fig. 2, *d*).

Now, what are we to think of these travelling pulses? Why does the luminosity move when there is water and remain steady when there is none?

It is evident that the travelling pulses represent the propagation of a wave of chemical action along the tube. There is a mixture of oxygen and phosphorus-vapor ready to unite. It does not at once do so, but chemical union is determined by the passage of the wave, just as in the firing of a train of gunpowder.

Nothing of this kind seems, however, to happen in the absence of water. Union occurs at once in that case, the phosphorus being consumed as soon as oxygen comes near it. The water holds up the combustion.

Now that matters have been brought to this point, you will not fail to be reminded of the experiment which I showed you before, when phosphorus was prevented from glowing by the presence of bisulphide of carbon vapor. Water, it is evident, acts like the other inhibiting substances, but less powerfully. This naturally suggests that we might get the travelling pulses on a more impressive scale by using a more powerful inhibitor than water. It is not desirable to have too powerful an inhibition, however, and I have found that camphor succeeds as well as anything. We have here a long horizontal glass tube with a mixture of camphor and phosphorus lying on the bottom. The tube is exhausted with an air pump, and air is allowed slowly to leak into it through a fine adjustment valve at one end. You will see bright luminous flashes pass down the tube at short intervals. The camphor vapor holds up the combustion until enough air has leaked in to make a mixture of favorable composition, the combustion starts, and the wave is propagated.

The period will evidently depend on how strong is the inhibiting action. I have used ammonia as a convenient inhibitor for illustrating this, for we may make its action as powerful as we please by using a more concentrated solution. The period of the flashes is increased accordingly.

If you have followed me so far, you will, I hope, have been convinced that the moving clouds of luminosity observed when the absorption of oxygen by phosphorus is nearly complete are linked up quite naturally with the existence of inhibiting substances.

I shall now direct your attention to another series of experiments which allow a further unification of the same kind. They began with the repetition of an interesting observation by L. and E. Bloch, which showed that if some phosphorus was placed in a glass tube it was possible to blow the glow away from it by a blast of air, and maintain it at a distance downstream. In this form I found the experiment rather difficult of control, sometimes succeeding and sometimes failing, for no very apparent reason. It all turned out ultimately to be a matter of temperature, a few degrees making the

whole difference. The next slide (Fig. 3) shows the arrangements which were made to bring this under satisfactory control. The phosphorus is a thin flat strip, cast into a suitable recess in the side of a water tank; thus its temperature can not differ much from that of the water. The latter can be varied at pleasure by the use of ice or warm water. A flat sheet of glass is held at a distance of a millimeter or two parallel to the phosphorus slab, and the air flows

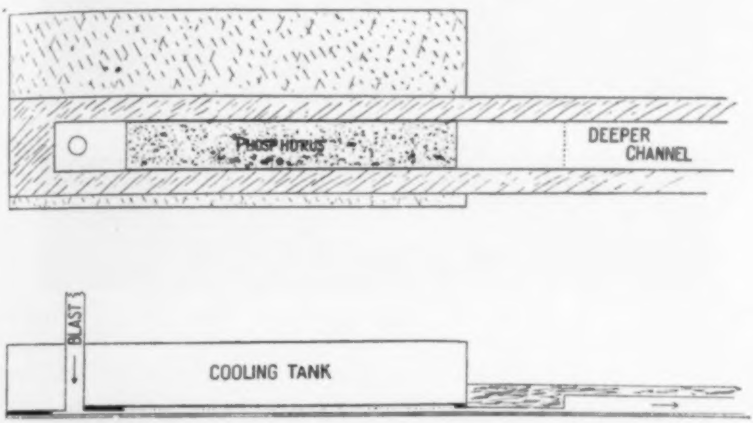


FIG. 3

between the two, being confined by suitable packing strips at the sides. The channel is prolonged downstream of the phosphorus, and is much suddenly deeper about two inches down. I should have liked to show you these experiments, but unfortunately they are not bright enough for an audience of more than five or six people, who can get quite close.

We must therefore be content with the photographs (Fig. 4, A and B). No. 1 shows how the phosphorus surface looks without any blast. V shows the glow blown right off, and maintaining itself downstream, where the channel is deepened. The dotted line (inked in on the photograph) shows the position of the phosphorus slab, which is quite dark. This is essentially the Blochs' original experiment. Interesting as it is, however, it by no means exhausts what we can learn with the arrangement described.

I examined the effect of changes of temperature, adjusting the blast in each case so that the glow was blown half way down the phosphorus strip. The velocity of blast necessary to do this was found to diminish enormously as the temperature was reduced. Thus in cooling from room temperature to near the freezing-point, the velocity diminished a thousand times. I next tried alternating the

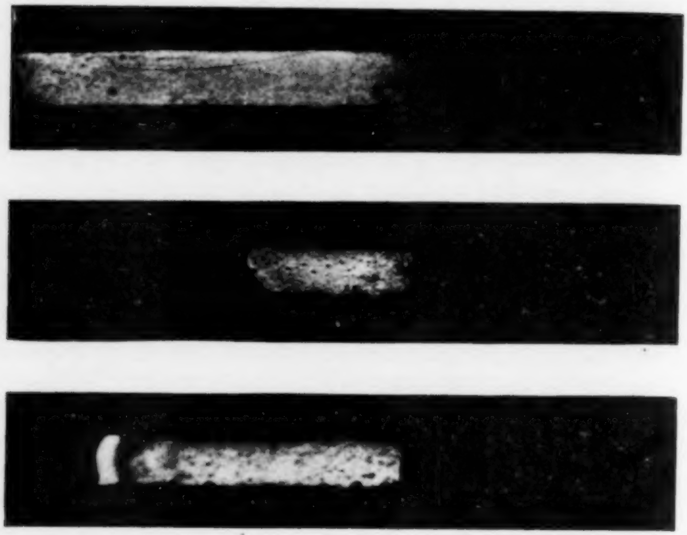


FIG. 4A

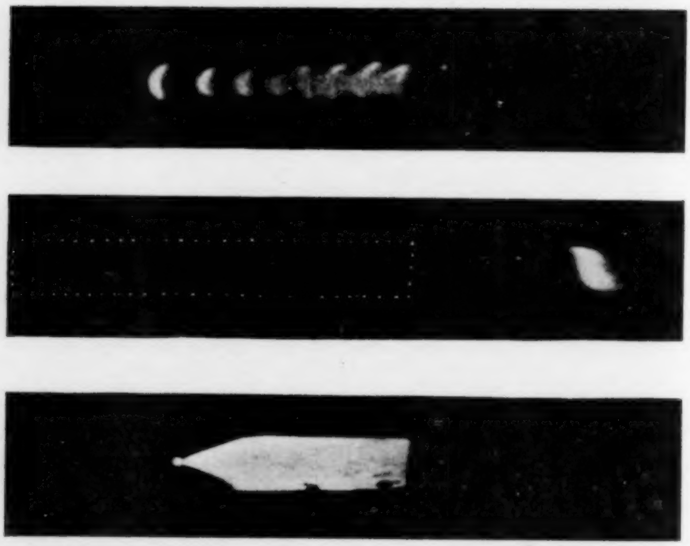


FIG. 4B

oxygen content, and found to my astonishment that enriching the air with oxygen had the same effect as cooling, and diminished the necessary velocity of blast in an equally striking degree. In both these cases the ultimate result, when the velocity had been reduced

to something of the order of 1 cm per second, was to make the glow flickering and uncertain of maintenance. On cooling a little more, or adding a little more oxygen, it went out altogether.

Now we must remember a fact, often enough insisted upon nowadays, that motion is relative. We have thought so far of the blast acting on the stationary cloud of luminosity, but we might equally regard the cloud of luminosity as propagating itself in the reversed direction through still air. When the air is much enriched with oxygen the necessary blast is gentle—in other words, the propagation is slow. It appears then that *extinction is the limiting case of slow propagation.* If we can trace the cause of slow propagation the cause of extinction will not be far to seek.

Before passing to this, however, I wish to draw attention to some curious effects met with in the course of these experiments on the blast. The same sequence of changes occurs whether we reduce the temperature or increase the oxygen content. I shall suppose, for definiteness, that the latter course is followed. When the oxygen is very little the glow tends to cling to particular spots, from which it can not readily be detached. II shows this to some extent, though other experiments were made in which it was much more striking. On close examination it appeared that these special spots were depressions in the phosphorus surface, when there was partial shelter from the blast. At these places the glow started, and when once started, it infected the gas downstream of it, and made the blowing away impossible. VI shows this very clearly. In this case a hole was made intentionally.

As we increase the oxygen content a bright luminous head develops, followed by a darker space, and then uniform luminosity. This bright head no doubt represents the combustion of the stock of phosphorus vapor accumulated as the blast passes over the dark surface.

The next stage, IV, is observed when the blast is so rich in oxygen that extinction is near. You see that a succession of bright heads has now developed. They are separated by dark spaces. This photograph was given four hours' exposure, and was not easily obtained: for some movement of the luminous heads is difficult to avoid during so long a time by eye observation. The heads were seen quite regularly distributed along the column. The confusion on the right-hand side is due to unavoidable shifts.

I could only attempt an imperfect explanation of these complex effects, shown in IV, and I will not trouble you with it on this occasion. Let us limit ourselves to the question of why propagation should occur at all, and why it should be slower when excess of oxygen is present.

In the analogy of a train of gunpowder, which I have used before, there is no doubt that propagation occurs primarily because each layer that has begun burning heats up the next layer, and causes it to burn too. In the case of phosphorus this explanation is hardly tenable, because the phosphorus vapor present is only a very small fraction of the atmosphere in which it is contained, and it can be calculated that it can not yield enough heat to raise the temperature more than a degree or two, which would not be enough.

We must look for some other way in which the action in one layer can help the action in the next one; and the suggestion I make is that the action is of the kind called catalytic. The products of combustion from one layer are able to promote the action in the next layer by a method analogous, *e.g.*, to that by which finely divided platinum is able to promote so many chemical actions between gases, some of them of industrial importance. It is true that this explanation is incomplete and in a measure speculative. On the other hand, as I hope to convince you, it covers many facts otherwise very hard to coordinate: and if any one is inclined to object to it, the most helpful thing he can do is to make his objection definite by calling attention to facts which are inconsistent with it, if there are any.

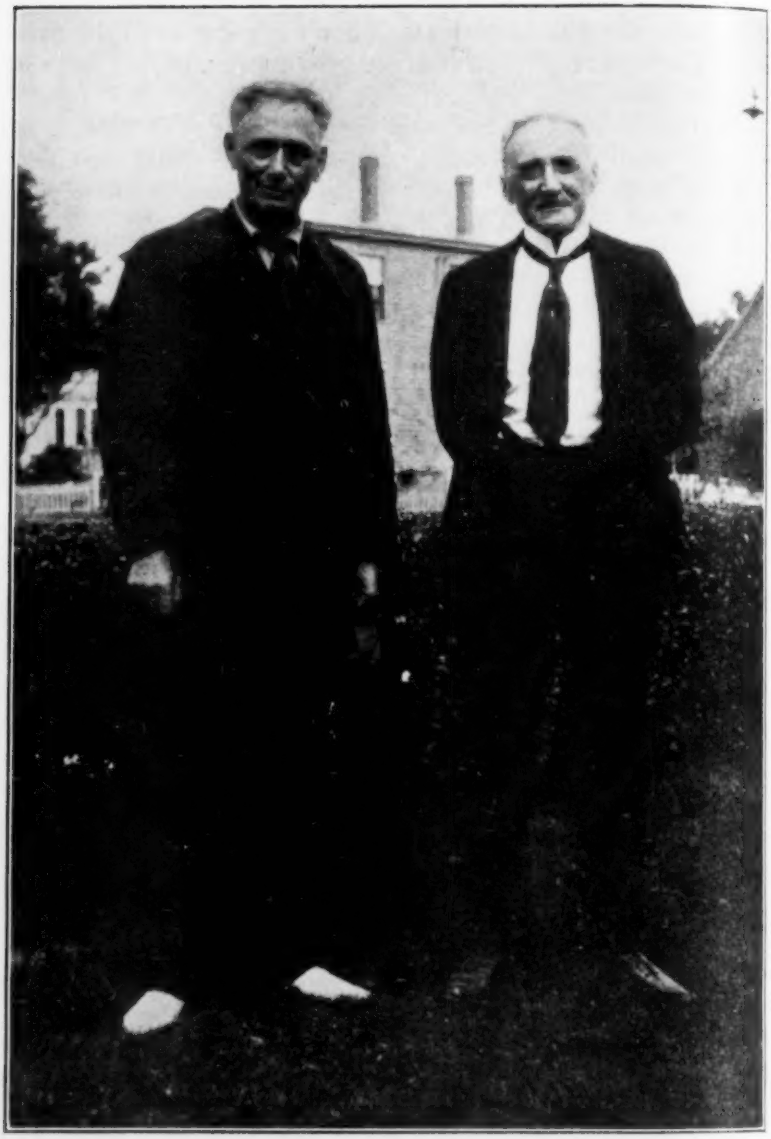
One of the most striking peculiarities of the kind of action I have referred to is the facility with which the catalyst is put out of order, or *poisoned* as the phrase goes. Several important industrial triumphs have depended on success in preventing this from happening. The exact condition of a surface capable of producing this effect is a very critical thing, and I believe that when the glow of phosphorus is *inhibited,* it simply means that the particles of phosphoric oxide, or other product of combustion, are spoiled, or *poisoned* by the condensation of molecules of the inhibiting substances upon them; and that this prevents them from assisting propagation. It is noteworthy that most of the inhibiting substances are easily condensable vapors, such as would be likely enough to act in this way. Oxygen is an exception, but it must be noticed, first, that oxygen will only act when moist; and, secondly, it has to be present in enormous excess—about 20,000 molecules of oxygen for one of phosphorus vapor—before it can quench the glow. Inhibitors like ammonia doubtless act by definite chemical union with phosphoric oxide.

Lastly, the view I have explained requires us to suppose that the combination is always breaking out sporadically at isolated centers, though in the presence of an inhibitor it fails to propagate itself.

I have recently been able to prove directly that this does in fact happen when oxygen is the inhibitor. When the gas-pressure was lowered the phosphorus glowed; but when it was raised again the

phosphorus went out abruptly, like a candle blown out. Nevertheless, under the latter condition, it was found by observations lasting over several weeks that a slow absorption was going on all the time, and it was found that this action occurred between oxygen and the *vapor* of phosphorus.

This whole research has been rather off the main stream of scientific inquiry at the present time; but I hope it has convinced you that there is still a fascinating field for research about phenomena which have been familiar for centuries.



JUSTICE LOUIS D. BRANDEIS AND DR. JACQUES LOEB

A photograph taken at Woods Hole by Julian Scott shortly before the death of Dr. Loeb.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

THE RACE OF THE RARE EARTHS

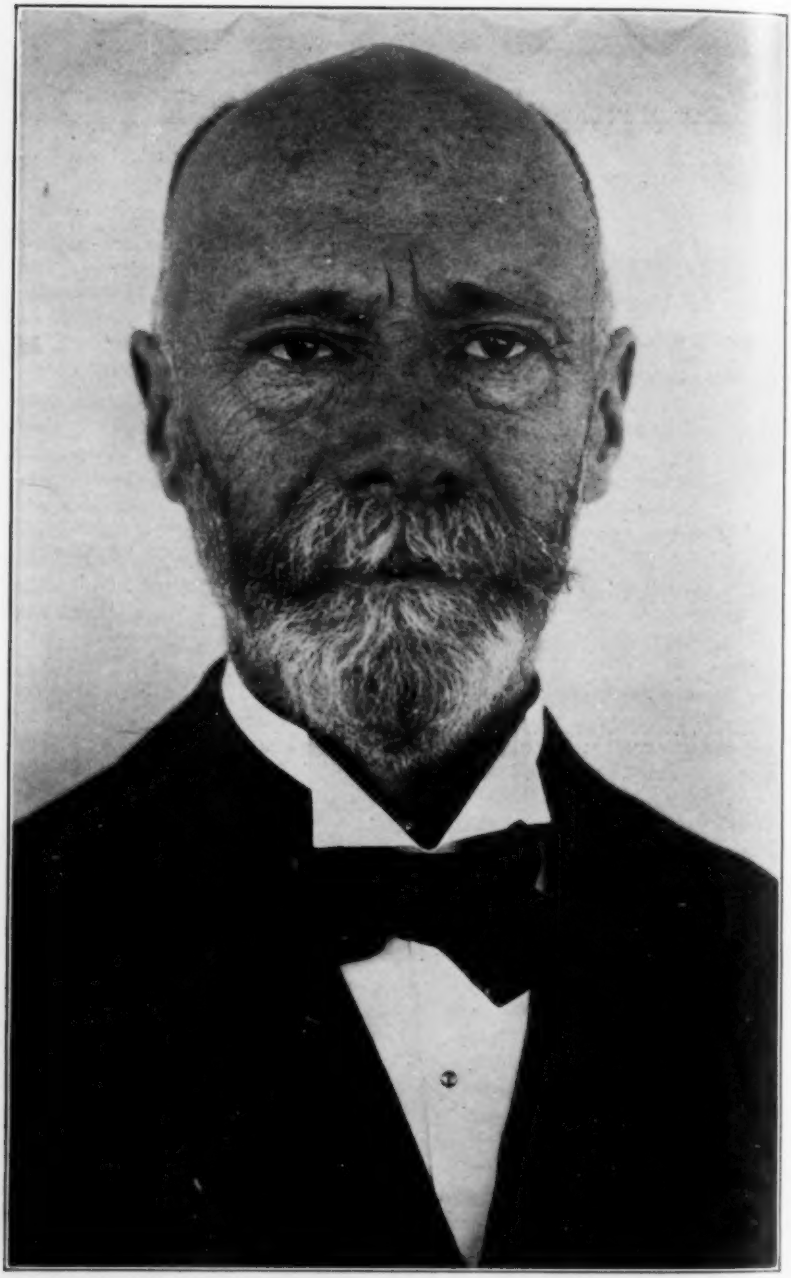
STRONGLY resembling a Marathon race is a method recently reported by a Columbia professor for separating from each other certain chemical elements that seem to have an inordinate tendency to stick together no matter what the chemist may do to break the family ties.

These elements, sixteen in number, are known collectively as the rare earths. They are really not rare at all, compared with a number of other elements, but, while the crude ores were rather easily and cheaply obtained, it required months and in some cases years to isolate the individual members in a pure condition. The consequence is that only in a few instances have scientists had the patience and the interest to carry out these fractionations which consist of from several hundred to as many as fifty thousand repetitions of the same operation. The result is that the rare earths are little known even to chemists, and since almost no pure material has been available for testing, they have found but slight commercial application.

The rare earths are like a family of brothers who have been brought up to be precisely similar in every thought and act. It is impossible to lure one away from the others by any ruse or temptation. Not that they are above temptation, however. The difficulty is that they all yield at once.

But complete identity of individuals is unknown either among the chemical elements or among human beings. The method devised by Professor James Kendall and Dr. Beverly L. Clarke is based on the fact that if all the brothers are started at the same time on a long race, slight individual differences in speed will cause each one to pass the judges' stand at a different moment. If now they are prevented from running back together, a separation is effected.

The apparatus used is a long glass tube provided with electrodes for passing an electric current of fairly high voltage through the contents of the tube. A hot solution is made of salts of the rare earths and to it is added some agar-agar, a substance which causes the liquid to set to a stiff jelly on cooling. This jelly is placed near one end of the glass tube, while on one side is placed a jelly containing an element of a speed slower than any of the rare earths, and on the other side a jelly impregnated with a faster element. The jelly is used simply to prevent the mixing that would occur with liquid solutions. The current when turned on affects the rare earth brothers and the two jailers on either side just as it would affect human beings. It creates a desire in all concerned to move away from there with the highest speed at their command. The faster and slower elements serve to prevent the rare earth section from spreading out, and so the section as a whole moves along the tube and the individual rare earths begin to arrange themselves in a series representing their respective speeds or abilities to get away from the electric energy that is urging them on. Provision is made for running the same sample through the tube



DR. WILLEM EINTHOVEN

Professor of physiology at Leyden, who has just been awarded a Nobel Prize, photographed as he sailed for home on the *Mongolia* on December 9, after a visit to the United States to deliver a series of lectures.

By United News Service.

a large number of times and when a sufficient separation has been obtained, the jelly is removed and quickly sliced into thin sections from which the individual rare earths may be extracted in a pure form.

Up to a few years ago about the only use for the rare earths outside of that of museum curiosities was in the preparation of mantles for obtaining the maximum luminosity from illuminating gas. Thorium and cerium are the metals chiefly used for mantles. With the advent of radio, however, a new use has been found for some members of this family as a coating for the filaments of the vacuum tubes, to enable radio fans to use dry cells instead of storage batteries. It seems highly probable that further research will unearth new and varied fields of employment for these interesting elements, and the new method of separation stands ready to furnish the rare earths in a much purer form, and at a minute fraction of the time and expense formerly required.

Incidentally, the new method is capable of application to other problems than that of the separation of rare earths. Hopes are entertained by its authors that through it will be found a means of purifying certain ores of radium which now practically go to waste, and thus of increasing the supply and lowering the cost of this element that is of so much importance to medicine and pure science alike.

THE GEOMETRY OF ETHICS

You may, if your arithmetic is erratic, add up a column of figures a dozen times and get different sums. Only one is correct. It is necessarily the same about the more complicated problems of life, only we can not see it so clearly. Elementary mathematics is the only science man has mastered so he can put real confidence in the results of his ratiocination.

Science, which aims at certainty, approaches it by the method of trial and error, thousands of trials, thousands of errors, before an approximation to the truth is attained. Truth is one; falsehoods are infinite. Nine tenths of the ideas that come into our heads are wrong. The object of education is to select the one that is right. Nine tenths of the impulses that beset us are wrong. The task of civilization is to suppress the nine.

No matter how complex the problem, there is never more than one right answer, one right way out, one straight and narrow path, hard to find and hard to follow, one road leading out of the maze of many false turns; all the others are blind alleys or paths that return upon themselves. It is an axiom of plane geometry that there can be only one straight line connecting two points. From the point where we are to the point where we wish to go, there is only one short straight road, all the other possible paths are more or less divergent and devious.

The rules of conduct are as invariable and absolute as the rules of geometry. The only difference is that we can not see so clearly in ethics as in mathematics. The falling of a fog makes our road obscure, but does not alter its length or direction. There is only one best move in a game of chess, whether we know what it is or not. There is only one wisest action in any emergency, whether we know what it is or not.

There are no indifferent actions, no equivalent choices. It may seem a matter of indifference which street you turn down in your morning stroll, but that is because you do not know what fate awaits you around the corner. If you turn down First Street you may be run over by an automobile. If you turn down Second Street you may meet a man who will

make your fortune. If you turn down Third Street you may catch a fatal microbe. If you turn down Fourth Street you may see the girl you want to marry.

If you knew, you could choose. But all the streets look equally inviting and not knowing which is the best you leave it to "chance." You toss up a penny, but it is not a matter of chance which face of the penny falls uppermost, for that is determined by the inevitable interaction of the forces of gravitation and rotary momentum.

Even if you could know what lay before you on each of the optional avenues, you would not necessarily be able to select the best. It may be that Second or Fourth Streets would lead you to more unhappiness than First or Third. Not knowing which is the most fortunate road you would be grateful if on that morning you should find all the others blocked by signs of "Street closed. Detour." You would be glad to be forced into good fortune if you could not find your own way. Nobody wants freedom of choice except in those cases where choice would lead him toward his goal, whatever that may be.

Nobody has a right to do wrong. Nobody but a congenital idiot would claim such a right and nobody but an incorrigible criminal would want to exercise it. Every sane man wants to do what is for his best interests and every good man wants to do what is for the best interests of others as well.

There can be no two opinions about this. The only thing we disagree about is as to what is for the best interests of ourselves and society. This is due solely to our ignorance, for if we all knew always what was best to do, we should of course all want to do it. But because we don't and can't always know, we have to allow considerable latitude as to thought and action, the more latitude in those fields where there is the more uncertainty. There is obviously but one course that ought to be pursued or would be pursued if we could know in advance the outcome of all our options.

ANARCHY IN THE HUMAN BODY

THE human system is ordinarily a well-ordered empire. The numerous organs and innumerable cells carry out their diverse duties in close cooperation and due subordination to the central powers. If the body is attacked, say, by the cut of a knife or an army of microbes, the blood cells hasten to fill up the breach in the wall or to overpower the invading host. Because of the vigilance and well-regulated activity of the cells, the ravages of wounds and disease may be staved off for seventy years or longer. And physicians have found that they can aid the defensive forces of the body by sterilizing open wounds or injecting antitoxins to destroy the foreign invaders.

But in case of an internal insurrection, the physician is comparatively powerless for he has no medicine that will distinguish between loyal and disloyal cells since they are of the same nature and origin. Such a cellular insurrection is cancer, and that is why no cure or preventive has been found for the disease like those for diphtheria and yellow fever. A similar situation prevails in international affairs. The League of Nations can intervene in the case of conflicts between nations but is powerless to prevent internal rebellion.

The cancer cells are carrying on the same commendable activities as the normal cells. They grow and subdivide at an amazing rate, but selfishly and without regard to the commonweal. It is as if New York City should fall into the hands of anarchists who were incompetent to maintain the

public services. For a time they would thrive on accumulated wealth and incoming supplies, but transportation would break down, the water supply and sewer system would fail, food would run short, and the population would perish from starvation and pestilence. The anarchistic colony would die at its center while continuing to spread into the surrounding country.

So the multiplying mass of cancerous tissue grows without developing, expands without organization, all cells of the same sort, equal in rank and alike in function; none in authority and none to obey; none to look after the interests of the community as a whole; none set to serve the rest as carriers or scavengers. So the cancerous colony, cut off from communication with general headquarters by lack of nerves, devoid of veins to relieve it of its waste products and of arteries to supply food and oxygen, dies and decays at the center, poisoned by its own pollution, while vigorously extending its conquests into the healthy tissue round-about.

To "increase and multiply" is the only law recognized by cancer cells. Some break away from the parent community and start new colonies in some remote part of the body. That is why it is so difficult to cut out cancer completely with the knife. A few cells transplanted from one animal to another will flourish in their new environment. They will even grow in glass if kept warm and well fed. They seem to be immortal and capable of infinite expansion so long as living conditions are favorable. In one American laboratory a single cancer strain has been kept in continuous existence by transplanting for thirty years, and it is calculated that if all the branch colonies had been allowed to grow and given a chance to expand as they would, the mass of cancerous tissue would fill the universe, all starting from some one cell that had gone wrong.

Sampson Handley says in the recent report of the Cancer Research Laboratories of the Middlesex Hospital, England: "It has to be remembered that man with his millions of cells has evolved from a single cell. It is hardly a matter of surprise if occasionally one of these millions of trained subordinate cells reverts to the ancestral, independent type, behaves like a unicellular organism, owning no allegiance to the cell community, whose ruin is the final outcome."

What starts the revolt? What is the origin of the impulse to anarchy?

This remains a mystery although the problem has been the object of research in well-equipped laboratories by skilled experimenters for many years. No microbe has so far been found present in all cancers and certain to produce them. Cancer is not, as commonly said, an exclusive disease of civilized man. It occurs among primitive peoples and animals, and has even been found in fishes. Cancer is apt to start at some point of chronic irritation yet not all such irritation causes cancer.

Three ways are known by which cancer is caused and by which it may be produced experimentally. One is by action of the penetrating rays of radium or the X-rays. These may either stimulate or destroy the cancerous tissue according to their intensity and duration. Another cause is a minute parasitic worm, carried by cockroaches, and when rats eat the cockroaches they are likely to get cancer of the stomach. The third cause of cancer is some substance contained in minute amount in the higher boiling fractions of coal-tar and petroleum. Workers about shale oil and tar stills are apt to get large warts on their hands that sometimes become cancerous and chimney sweeps may get cancer from the soot. Coal tar put on the skin of mice will cause cancer but not on rats.

THE RADIO PHOTO-LETTER MACHINE

C. Francis Jenkins, known for his work in motion-picture projection and the transmission of pictures by radio, who is on the left, is showing his radio photo-letter machine to J. Horace Rogers, who has done important work on underground wireless and radio transmission; Alfred Stearns, in charge of radio at Washington; Curtis D. Wilbur, secretary of the navy, and Emile Berliner, known for his important inventions including the loose contact telephone transmitter which is also used in radio.

Until the cause of cancer is discovered, a cure can hardly be hoped for. But there are a few well-authenticated cases of spontaneous cures, and recent experimentation points the way to a possible conquest of the disease. In the Middlesex Hospital certain hopeless cases have been treated by injecting doses of cancer cells that had been killed by exposure to radium rays, and encouraging results are reported from this treatment.

DEATH-DEALING AND LABOR-SAVING RAYS

Chemists in various parts of the world are busy trying to break open the safe that contains the most wealth of any in the world. This safe is the atom. For wealth is the product of work and work is the application of energy, and the most powerful and concentrated form of energy consists of the balanced forces of the positive and negative electrical particles inside the atom.

These forces are most intense in the nucleus of the atom, the sun of the atomic system. The atom of radium is in an unstable state and occasionally throws off a fragment from its nucleus with a velocity of ten thousand miles a second. This speed is twenty thousand times faster than a rifle

bullet, and consequently its energy is four hundred million times greater than that of the bullet, mass for mass.

Now if it were possible to excite a similar instability in the atoms of other elements than radium, we might get enormous streams of energy out of them. Is it possible? Most scientists to-day are disposed to doubt it.

But at least one reputable electrician, Dr. T. F. Wall, of Sheffield University, England, thinks that it can be done and he is trying to do it. His apparatus is based upon a simple principle that is familiar to everybody who has played with a coil of wire and a magnet. Sticking the magnet into the coil starts an electric current, that is to say, a stream of electrons, running through the wire, and conversely, running an electric current through the wire will create a magnetic field inside the coil.

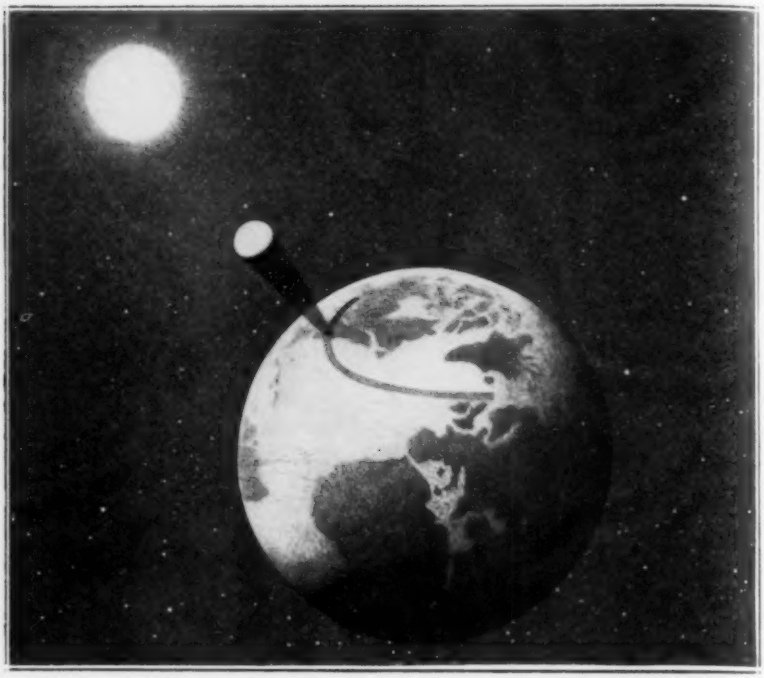
Now the electrons, revolving in their orbits around the nucleus like the current in the coil, must produce a powerful magnetic field. Conversely, we would suppose that if we brought more powerful magnetic forces to bear upon the atom, its electrons would be disturbed in their orbits and perhaps even driven out of the atomic system altogether. If, for instance, a giant star with more gravitational force than our sun should wander into our vicinity, it would create a commotion in our solar system and perhaps a scatteration of the planets.

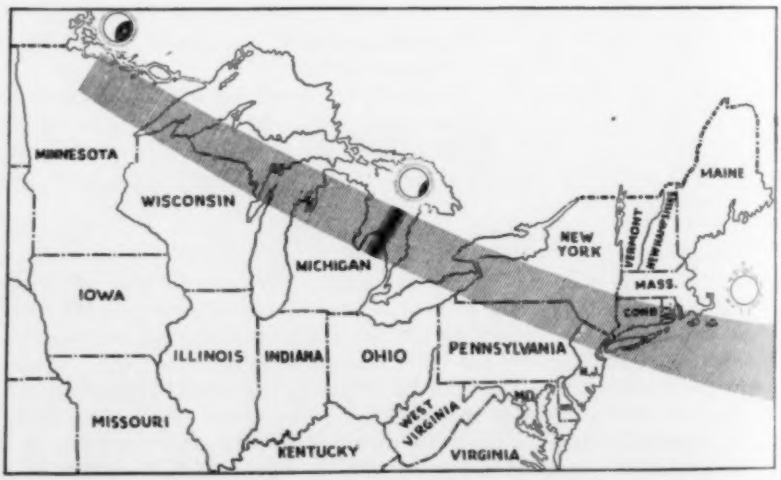
But the magnetic field inside the atom is vastly more intense than any that has hitherto been produced artificially. How then can we hope to upset its equilibrium? But Dr. Wall has the idea that the rapid and rhythmical repetition of even a weaker power may derange the revolutions of the electrons, just as a suspended cannon ball may be set swinging by repeated taps with a light mallet.

By passing an extremely powerful oscillating current through a coil, he hopes to get a sufficiently intense magnetic field inside the coil to overpower and counteract in some measure the magnetic field inside the atoms. From static condensers of large capacity and high voltage, he obtains a current of 50,000 amperes, but as it runs only a fraction of a second, it does not burn up the wire. With this apparatus he is able to obtain a field amounting to some millions of magnetic units.

Dr. Wall is reticent about his results, but is willing to disclose the purpose of his experiment and its possibilities. In the latest number of *Discovery*, he says: "Quite frankly stated, the ultimate aim is definitely to disturb the atomic structure for the purpose of releasing some or all the latent energy of the atom."

Since he has been credited—and discredited—in the press with the design of producing a "death ray," it is well to quote his own words on this point. He says that the energy so released from the interior of atoms "presumably would be in the form of rays of energy of some possibly quite unknown type." The possibility of their application to warfare would be a serious national concern, for "it is reasonable to suppose that if intense magnetic fields are found capable of releasing the atomic energy, similar magnetic fields may provide the solution for the control, and concentration of the released energy in the form of a ray or beam like the beam of a searchlight. If this is found practicable it would probably result in a very simple control apparatus. Such a ray or beam of energy when directed on any given object would possibly be capable of yielding up its energy in the form of heat, thus superseding the use of coal, oil or other fuel. What, however, is far more probable is that new forms of motors





THE PATH OF THE TOTAL ECLIPSE OF JANUARY 24, 1924

Courtesy of the Editor of *The Scientific American.*

would be developed which would be able to use the energy of the beam directly without the need of any intermediate conversion into heat."

We must admit that Dr. Wall has reason for his surmise that in the present temper of the human race such a new found force would be first applied to the killing of human beings and the destruction of their property. But other inventions, quite as affrighting at first sight, have in time been tamed and set to the service of man. The weapons of Mars ultimately become tools in the hands of Minerva.

But it would be premature to worry over its possibilities in warfare or to rejoice over its potentialities in industry until it is proved that such a form of radiant energy can be produced in quantity from the atom and that it does not require more energy to release it than can be obtained from it.

TESTING AND TRAINING THE MEMORY

By Professor R. S. Woodworth, Columbia University

A young college freshman came to see me to ask my advice about his poor memory. His memory was so poor, he said, that he simply could not learn his lessons no matter how much he worked over them. I put him through some memory tests and found that his memory was perfectly normal. Then I asked him how he went to work to learn his lessons, and I found that he had carried over into college his high school habit of simply reading his lessons through and through in a blind passive way. A long college lesson in history he would read through once, then read it through a second time, then a third and sometimes a fourth time, and yet when next day questions were asked upon this lesson he had forgotten the answers. Now the fact was that he had not forgotten the answers, but had never known them, for he had not analyzed the reading, understood it or picked out the important points. It was a lack of good management rather than of power of memory. I advised him to read the lesson through once, then to review and analyze it mentally, and finally to consult the book again and check up his analysis. This procedure he found to save him much time and give much better results.

If you ask us what memory is, you see that it amounts to this: You do something all by yourself, which you originally needed assistance to do. If you remember a person's name you can call him by name on sight without any assistance. When you first met this person you had assistance. Some one told you his name. Good management demands that when you have the assistance at hand you should so use it as to do, right then and there, the very thing that you wish to do later without assistance. When someone has just told you the stranger's name you should look at the stranger and call him by name, either aloud or silently, and so prepare to do this very thing at some later time without assistance. This is the principle of all sound memory training.

Psychologists, after testing the memories of many people, are able to announce two very encouraging results. First, that nearly every one has more power of memory than he imagines, and second, that intensive training produces great improvement in memory. But it should be added as a very important qualification that training does not develop the general faculty of memory, but simply increases the power of doing the particular kind of memory job that is practiced.

The first step towards effective memory training is to decide exactly what sort of memory work you need to improve, so as to devote your effort to this particular job. If you wish to improve your memory for poetry, you must practice memorizing poetry. If you wish to improve your memory for names and faces, you must practice connecting the name with the face. If you wish to improve your memory for telephone numbers, you must practice connecting telephone numbers with the names of subscribers. If you wish to improve your musical memory you must practice memorizing music. If your wife complains because you can not remember much of interest from your day's experiences to enliven the supper table, what you need to practice is the taking note of interesting items as they occur and then recalling these when the time comes. Great improvement can be made in any of these memory jobs, by devoting time and effort to that particular job. No doubt an expert psychologist adviser could assist any one to improve his memory work, but an intelligent person can do much for himself, once he knows that he needs to train himself for specific memory jobs, and that the problem is one of management rather than of inherent memory power.

The first step is to see exactly what memory job needs to be perfected. The second step would naturally be to proceed to practice this particular job. But just here a very curious state of affairs often comes to light. The man who says he very much desires to improve his memory yet finds it very irksome to work at the details of this particular job. In a way he is indifferent or even unwilling to do this job well. He experiences an inner resistance that interferes with his progress.

If this seems almost an impossibility, consider once more the sad case of the man whose wife finds him very unsatisfactory as a provider of interesting news. Is this the sort of man who snaps up eagerly every bit of interesting gossip or happening, and who anticipates the pleasure of recounting his news at the supper table? Does he relish the job of gathering news items for feminine consumption? Possibly not. Quite possibly he is the kind of man who thinks this beneath his dignity. He doesn't regard this as his job in any big sense. When it comes down to the actual working of this job, he rebels against it. This inner resistance is going to interfere considerably with the improvement which he might make. The chances are that he never will enter into this new game heartily, and will never become a shining example of success in this sort of memory work; but if he can overcome his own resistance it is in his power to improve. It has been done.

Poor memory is due to poor management rather than to an inferior faculty of memory. Any sort of memory can be improved if one discovers exactly what needs to be improved, and if one can play the game heartily.